Part V　Planned Maintenance

PM is needed in case where there are no operators and / or in case where five senses or simple means to detect anomaly cannot be utilized.

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1. Introduction
2. Countermeasures Against Machine Breakdowns
3. Step by Step Approach to Establish a Planned Maintenance System
4. Shutdown Maintenance
5. Establishment of CBM
6. Spare Parts Management
7. Maintenance Cost Management and Maintenance Management System

Appendix : Maintenance Skills Assessment

1. Introduction

1.1 Special Features of Process Industries
1.2 Common Problems and Their Causes
1.3 Various Maintenance Activities
1.4 Category of Maintenance Activities
1.5 Special Maintenance Activities
1.6 Structure of Planned Maintenance
1.7 How to Select a Proper Maintenance
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1.10 Planned Maintenance System Showing Allocation of Responsibility
1.11 Classification and Allocation of Maintenance Tasks
1.12 Economic Justification of PM System

Special Features of Process Industries

* **Diverse production systems**

* **Diverse equipment**

Production processes consist of a combination of :

① Unit operations such as pulverization, dissolution reaction, filtration, absorption, concentration, crystallization, separation, molding, drying, cooling and screening

and

② the handling and transportation of various substances.

Equipment includes :

① static units such as columns, tanks, heat exchangers, kettles and furnaces

② rotating machinery such as pumps , compressors, motors and turbines

③ the piping, electrical and instrumentation systems that connect them.

* Use of static equipment

The special nature of such equipment requires techniques for diagnosing corrosion, cracking, burning, blocks, leaks, and so on.

* **Centralized control and few operators**

* **Diverse equipment-related problems :**

In addition to *blocks, leaks* and *corrosion,*

cracking, rupture, seizure, fatigue, slack,

parts falling off, wear, distortion, burning,

short-circuiting, faulty insulation,

wire breaks, mis-operation, current leaks,

overheating, etc. take place.

* **High energy consumption**

* **Standby units and bypasses commonly used**

* **High accident and pollution risk**

① Some processes handle hazardous or poisonous substances and are operated at high temperatures and pressures risking explosion and pollution of the plant and its surroundings.

② This makes strict plant management essential.

* Poor working environment

Such conditions as scattered, overflowing, leaking, etc.

frequently cause equipment problems.

* Shutdown maintenance

① Carefully planned, systematically implemented shutdown maintenance is considered the most effective way of preventing breakdowns.

② Since shutdown maintenance is time-consuming and labor-intensive, it is also expensive.

③ Finding the most effective way of performing shutdown maintenance in view of its cost and the losses it incurs is therefore a perennial concern in process industries.

Common Problems and Their Causes

Obvious Problems and Losses

1. Equipment failures or process problems causing shutdown
2. Quality abnormalities
3. Unit-consumption abnormalities
4. Capacity reductions
5. Safety and environmental problems

Equipment Disorders and Hidden Defects

Static Equipment

1. Changes in equipment interiors (deformation due to corrosion vibration, loose or fallen-off parts, etc., contamination, blocks, erosion, internal leaks, degradation of materials)
2. Changes in equipment exteriors (leaks, corrosion, degradation of materials)
3. Changes in measuring and control equipment (broken wires, short- circuits, contamination, blockage, degradation of materials, programming errors, spurious signals)

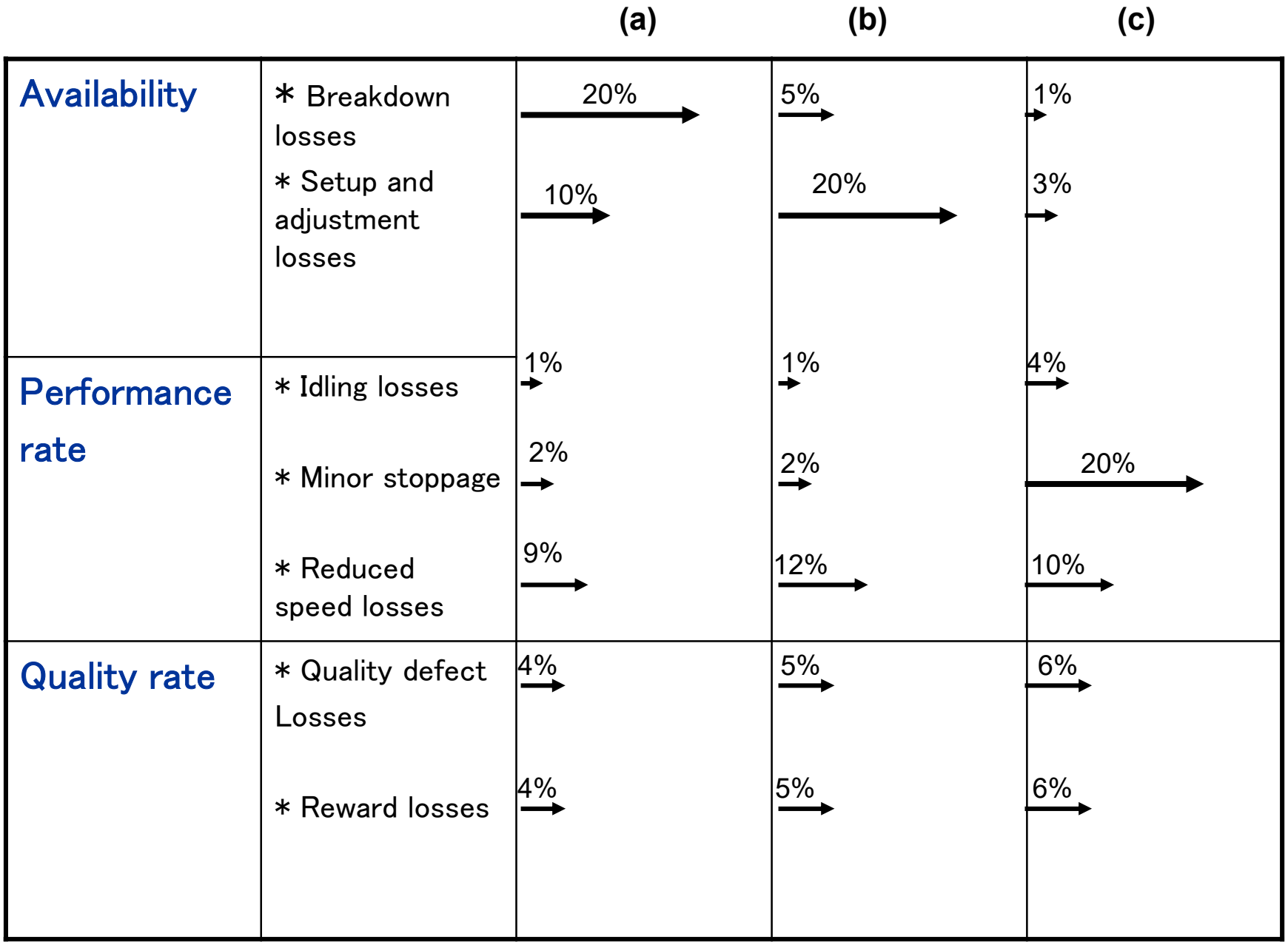
Rotating Machinery

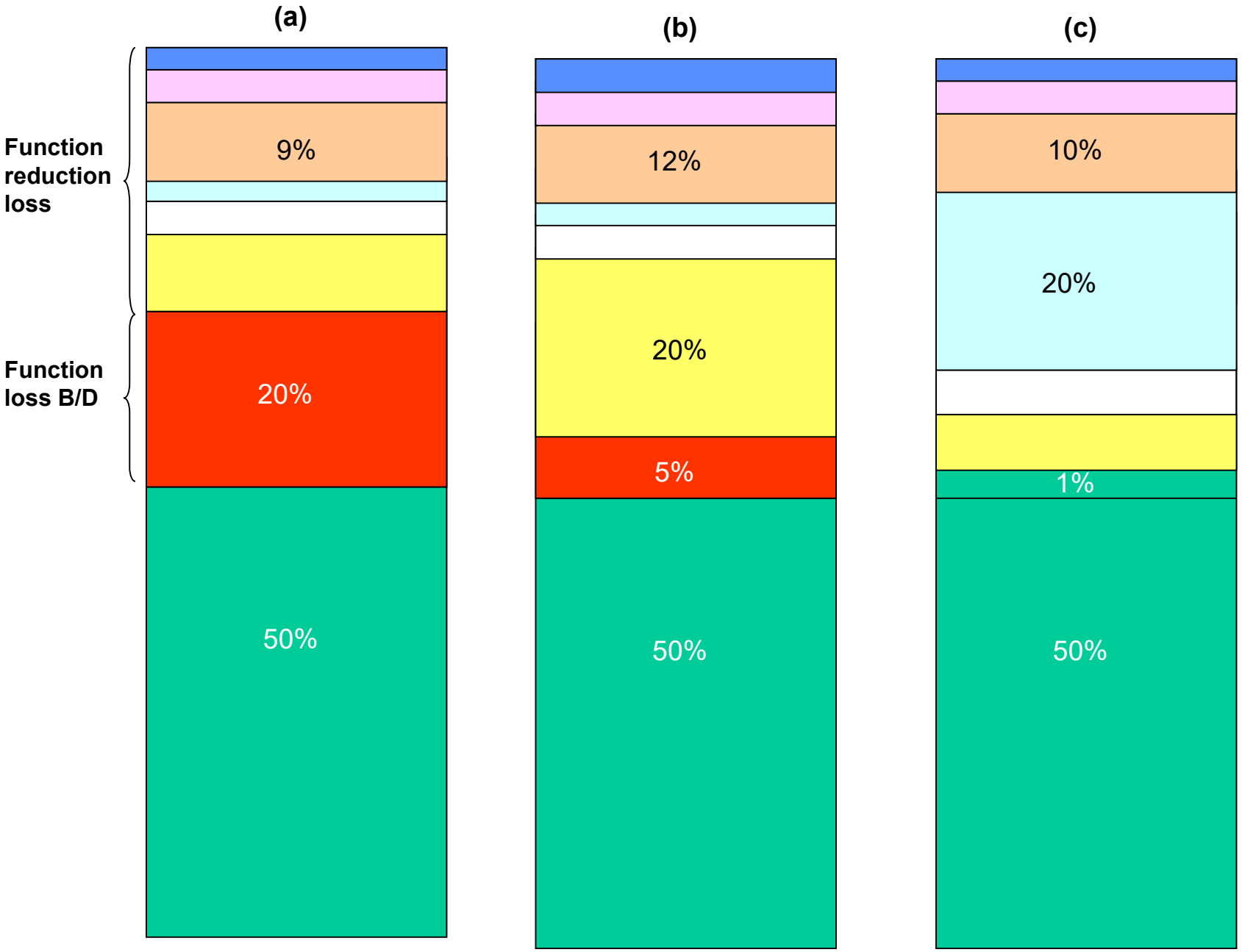
1. Changes in machine interiors and exteriors (deformation due to corrosion, vibration, loose or fallen-off parts, etc., contamination, blocks, leaks, erosion, degradation of materials)

The two types of breakdown

Breakdown

- Function-loss breakdown
  - (This is likely to be caused by the growth of a minor defect)
  - ● Breakdown in which all equipment functioning stops. Even if the cause lies in a single specific function, the breakdown results in the cessation of all equipment functions.
  - ● Breakdown which is caused by a partial function stopping and will eventually lead to the stoppage of all the function of equipment
- Function-reduction breakdown
  - (In many cases, function-reduction breakdowns account for the largest proportion of overall equipment losses.)
  - ●Problems related to deterioration are considered function-reduction breakdowns, or breakdowns resulting in various losses (defects, minor stoppages, etc.)


(a)
(b)
(c)
Availability
* Breakdown losses
* Setup and adjustment losses
20%
10%
5%
20%
1%
3%
Performance rate
* Idling losses
* Minor stoppage
* Reduced speed losses
1%
2%
9%
1%
2%
12%
4%
20%
10%
Quality rate
* Quality defect Losses
* Reward losses
4%
4%
5%
5%
6%
6%


(a)
(b)
(c)
Function reduction loss
Function loss B/D
9%
20%
50%
12%
20%
5%
50%
10%
20%
1%
50%

When some part, if it breaks, has a risk of creating a huge damage, then it must be placed to expose it to human eyes such that its anomaly can be detected quickly enough even if such placement looks ugly. (eg. The rupture of hoses, breakdowns of cables)

Normal machine component deterioration

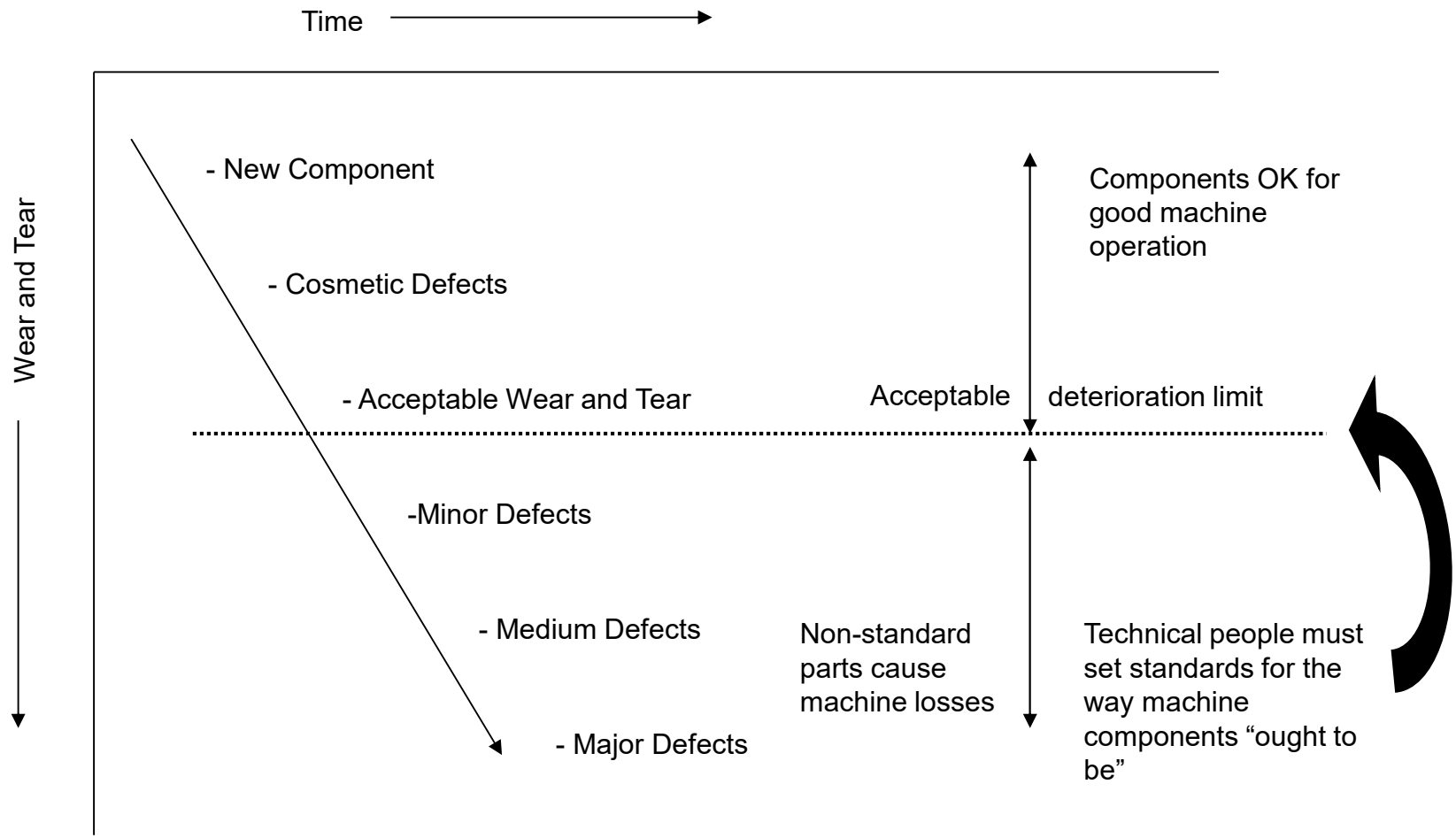
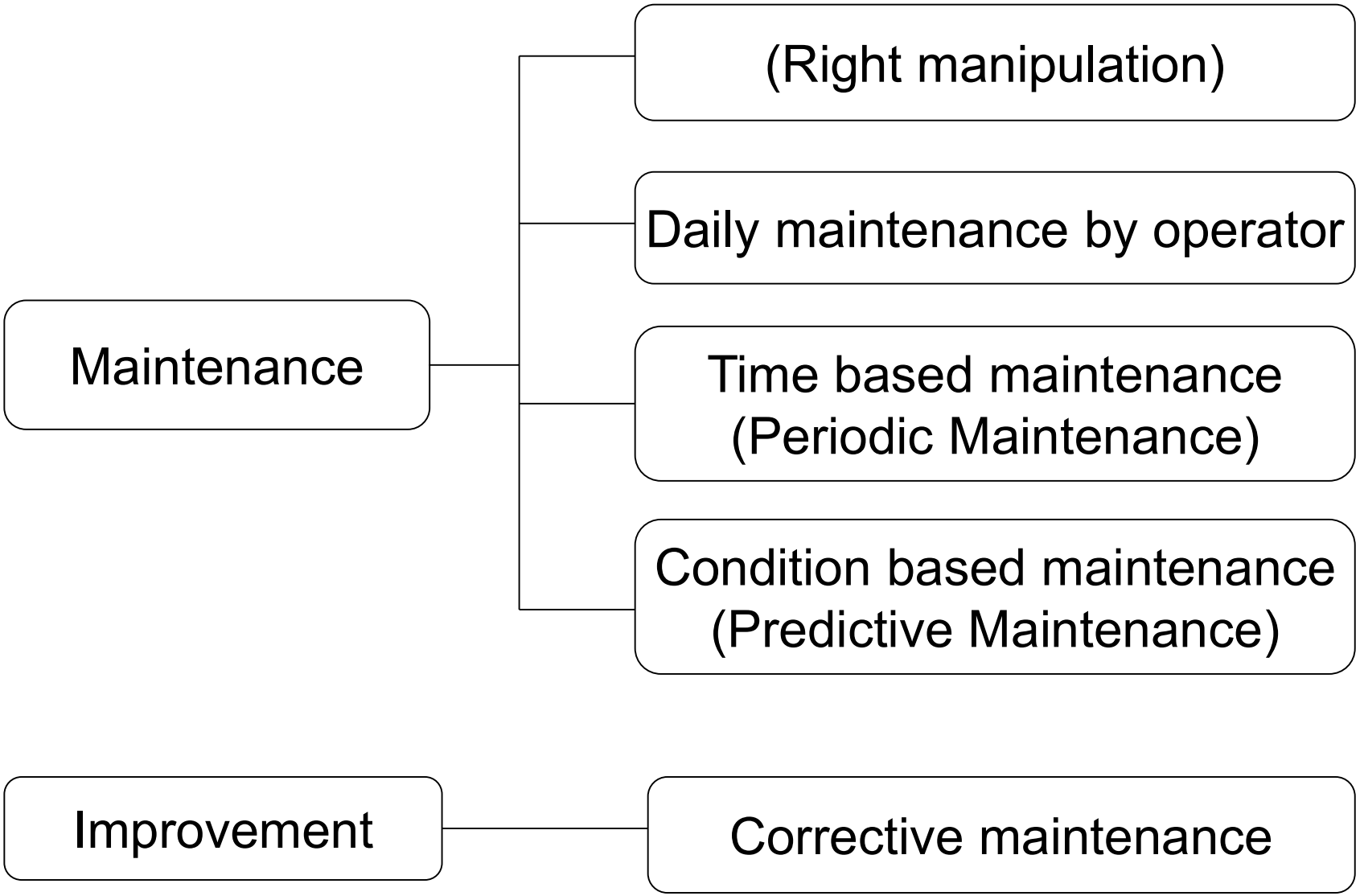


Figure. Normal machine component deterioration

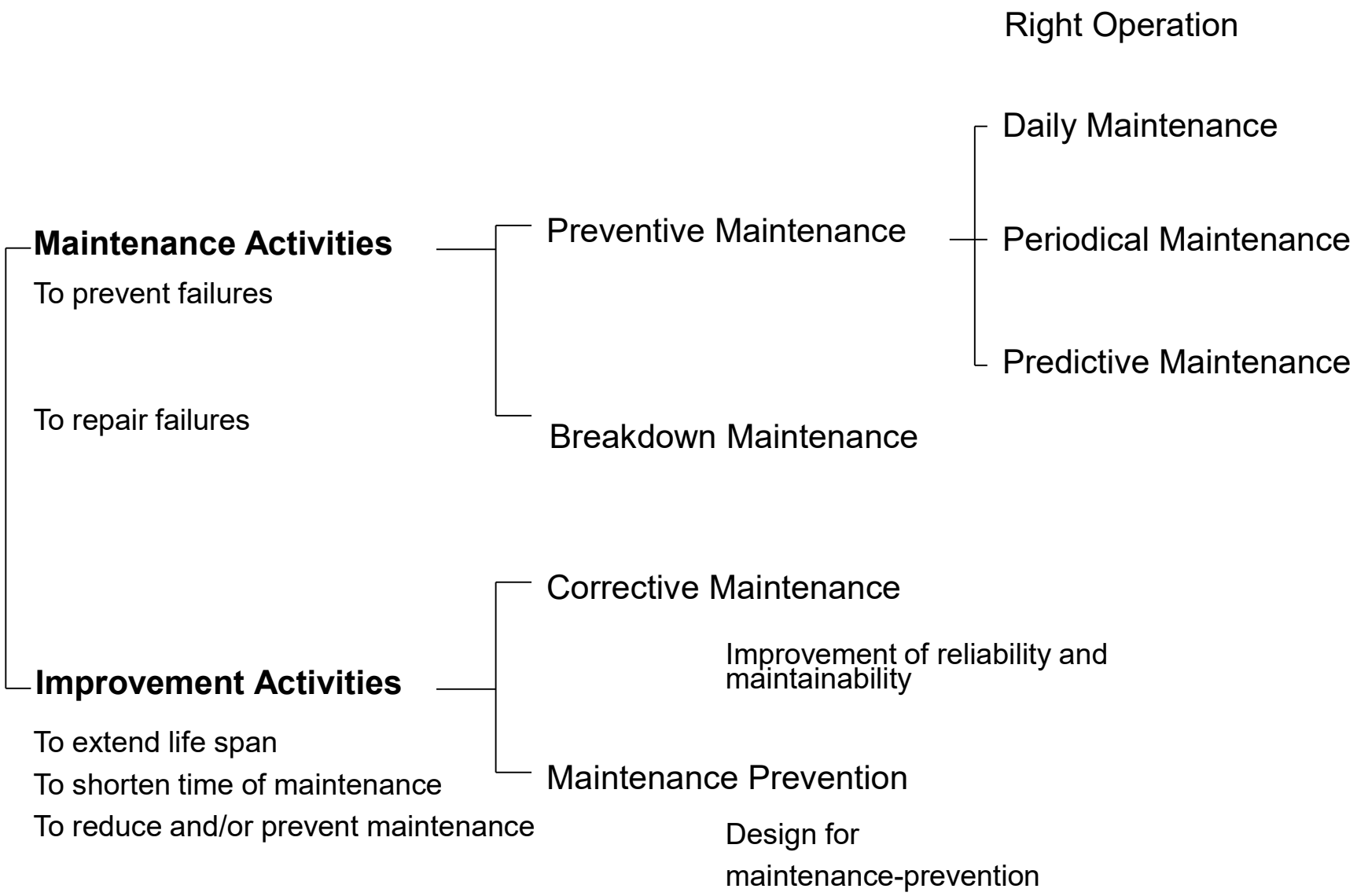
Various Maintenance Activities



Maintenance techniques and activities

Normal Operation	Correct operation, correct adjustment, correct setting (preventive of human errors)
Preventive Maintenance	Daily maintenance (basic equipment conditions, checking, minor servicing) Periodic maintenance (periodic checking, periodic overhaul inspection, periodic servicing)
Predictive Maintenance	Condition monitoring, medium-interval and long-interval servicing
Breakdown Maintenance	Prompt abnormality detection, emergency repairs, recurrence prevention (troubleshooting)

Category of Maintenance Activities



Breakdown & Minor Stoppage Definitions

Type of Loss	Definition
Breakdown	An equipment stoppage **greater than 10 minutes** due to a component failure or breakdown. Restoring normal conditions normally requires action by the craftsman to repair the equipment by: • Replacing a faulty part, resetting a parameter, adjustment (mechanical or electrical) • Operator error, supplier, material issues
Minor stoppage (automated equipment) (plaster & value added lines)	An equipment stoppage due to a failure or error in automatic handling, processing or assembly of parts or work pieces which are often within specification. Restoring normal conditions normally requires action by the operator to reset and/or reactivate the equipment in **less than 10 minutes**, and that is usually all that is required to overcome the equipment stoppage. The loss can also be manifested as a yield or usage issue.

Operations and Maintenance Mindsets

Maintenance is a necessary evil that never does what you want.
That is why maintenance is made. If machines do not breakdown, maintenance is not needed.

Maintenance is the hub of good manufacturing.
With good maintenance, machine should not breakdown.

Breakdown Maintenance

On failure, breakdown maintenance can be effective if applied correctly.

For example, the impact of the failure has been ASSESSED as low or zero in terms of :

Safety, Delivery, Quality, Cost and Productivity

(SDQCP)

The maintenance strategy for these items of equipment is to ALLOW it to fail.

Advantages

* Low cost if correctly applied
* Requires no advanced planning other than ensuring spares are available.

Disadvantages

* No warning of failure – safety risk
* Uncontrolled plant outage – production losses
* Requires large standby maintenance team

Time Based Maintenance

Mostly widely used form of maintenance

It is most effective if implemented as equipment begins to wear out and failure probability increases.

Planned maintenance tasks are often grouped together into maintenance downtimes or windows to minimize the total number of planned maintenance stoppages per year.

This strategy is not optimum as the lack of basic conditions will make the prediction of the replacement frequency very difficult. However once the basic conditions are restored this will be an excellent tool and is the prerequisite to Condition Based Maintenance (CBM).

Advantages

* Failures reduced
* Labour used cost-effectively
* Maintenance planned well in advance (provision for labour and material)

Disadvantages

* Maintenance activity and costs increased
* Unnecessary and invasive maintenance is carried out
* Applicable only to age related deterioration
* Maintenance sometimes induces failures (infant mortality)

Condition Based Maintenance

CBM relies on the fact that the majority of failures do not occur instantaneously but develop over a period of time.

CBM involves recording some measurement that gives an indication of machine condition.

* Temperature increase on an insulation surface
* Vibration increase on a bearing housing

Condition monitoring is not purely a “high tech” tool to be used by highly skilled engineer

* Operators who work with equipment every day can listen to equipment and identify changes in noise levels and vibrations. Temperature changes can be felt and these give warnings that something is “not right”. An investigation can then be carried out to identify the exact problem.

Advantages

* Maximizes equipment availability.
* Some forms of inspection utilizing human senses can be inexpensive.
* Allows shutdown before severe damage occurs.
* Cause of failure can be analysed.
* Maintenance can be planned.
* Labour can be organised.
* Spares can be assembled.
* Some CBM tools are very basic, such as temperature and pressure monitoring.

Disadvantages

* Vibration monitoring, thermograph and oil debris analysis require specialized equipment and training.
* A company must carefully choose the correct technique.
* A period of time will be required for trends to develop and then machine condition can be assessed.

Corrective Maintenance

This is not actually a maintenance strategy.
It is a combination of the other maintenance strategies and is used to improve maintenance practices & update the design of the machine.

Since maintenance people know which parts of equipment breakdown, they are the best people to make corrective maintenance. Maintenance people should mainly be engaged in corrective maintenance.

Effective method of solving a recurring problem.
However it can easily be inappropriately utilised.

Corrective Maintenance

Process

1) Identify exactly what the root cause of the problem is.
2) Is it possible to monitor the condition at this problem area? If so, it may be cost effective to monitor the condition and take action as necessary.
3) If this is not the case; can the problem be designed out? If it can, what will this involve and can it have any adverse effects elsewhere?
4) Once the procedure has been thoroughly developed, proceed with the design out project.
5) Finally if design out is been considered, is it a symptom that mistakes were made during the original designing of the equipment?

Advantages

* Some minor design out projects can be inexpensive and guaranteed to work
* A recurring problem can be completely resolved.

Disadvantages

* The root cause of the problem may get missed in the exercise.
* A Larger design out projects can prove to be very expensive.
* Production can be disrupted for a considerable period of time with larger projects.
* The expected result may not materialise.
* Unexpected problems may occur as a result of a major project.
* Solving a problem in one area may overload and cause problems in another.

Opportunity Maintenance

This is not actually a maintenance strategy but a combination of planned maintenance and breakdown maintenance.

One major issue withy maintenance is access to the machines for inspection and improvement work.

Inspections during routine down times can identify unexpected tasks that need to be carried out, but time does not allow it to happen. These tasks can be recorded on a maintenance management system and scheduled into the first available down time.

The maintenance department prepare materials, tools and improvement parts for the task and wait for the opportunity when the machine is next stopped.

Special Maintenance Activities

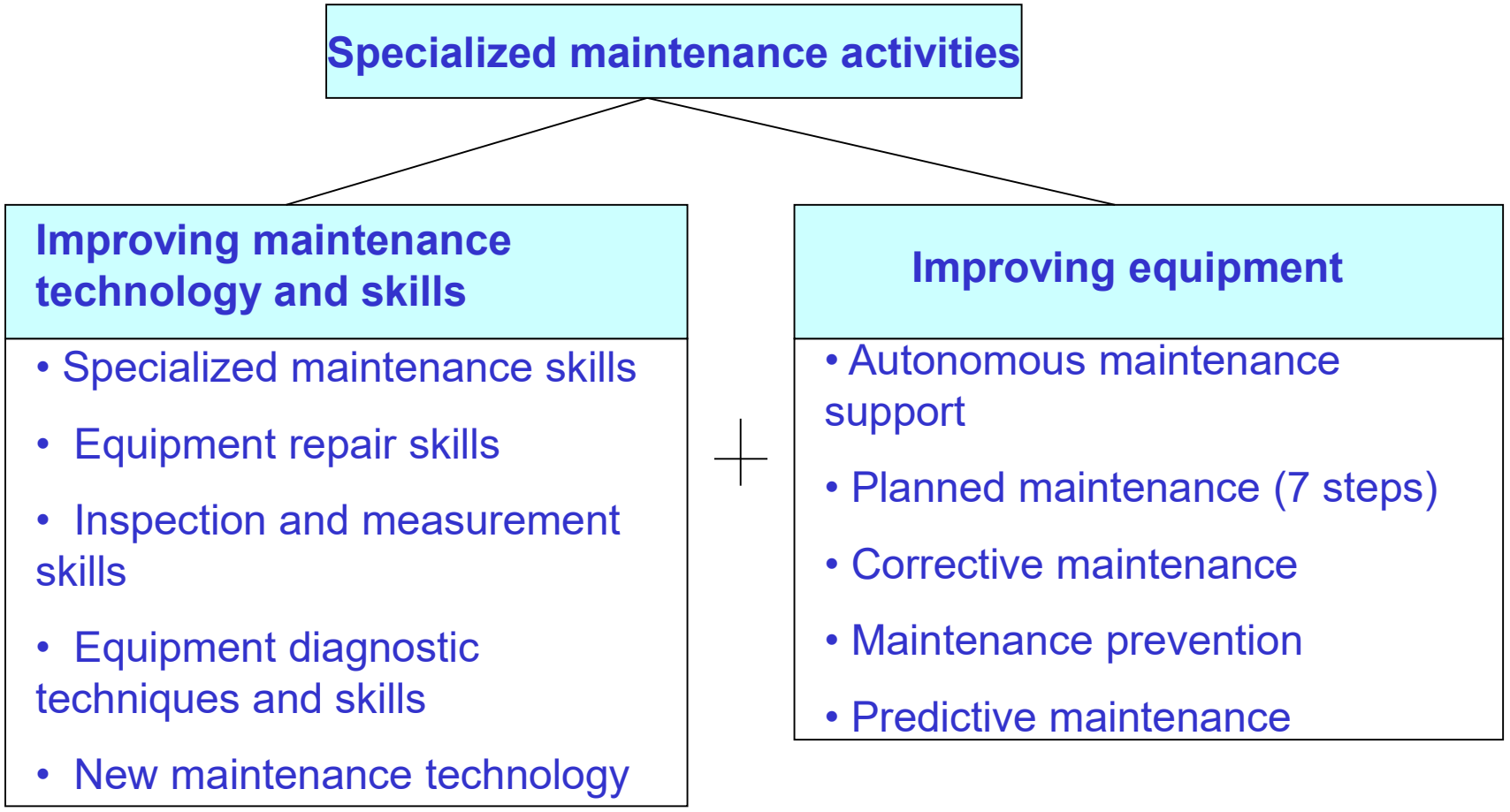


Figure : The twin activities of specialized maintenance

Structure of Planned Maintenance

What equipment?

Classify machines into different categories based on priority from the viewpoints of P, Q, C, D, S and M.

What part?

Practical approach : Step by step approach by A.M. and P.M.

Theoretical approach : FMEA, FTA, PPA, RCM, etc.

What type of maintenance ?

BM, TBM, CBM?

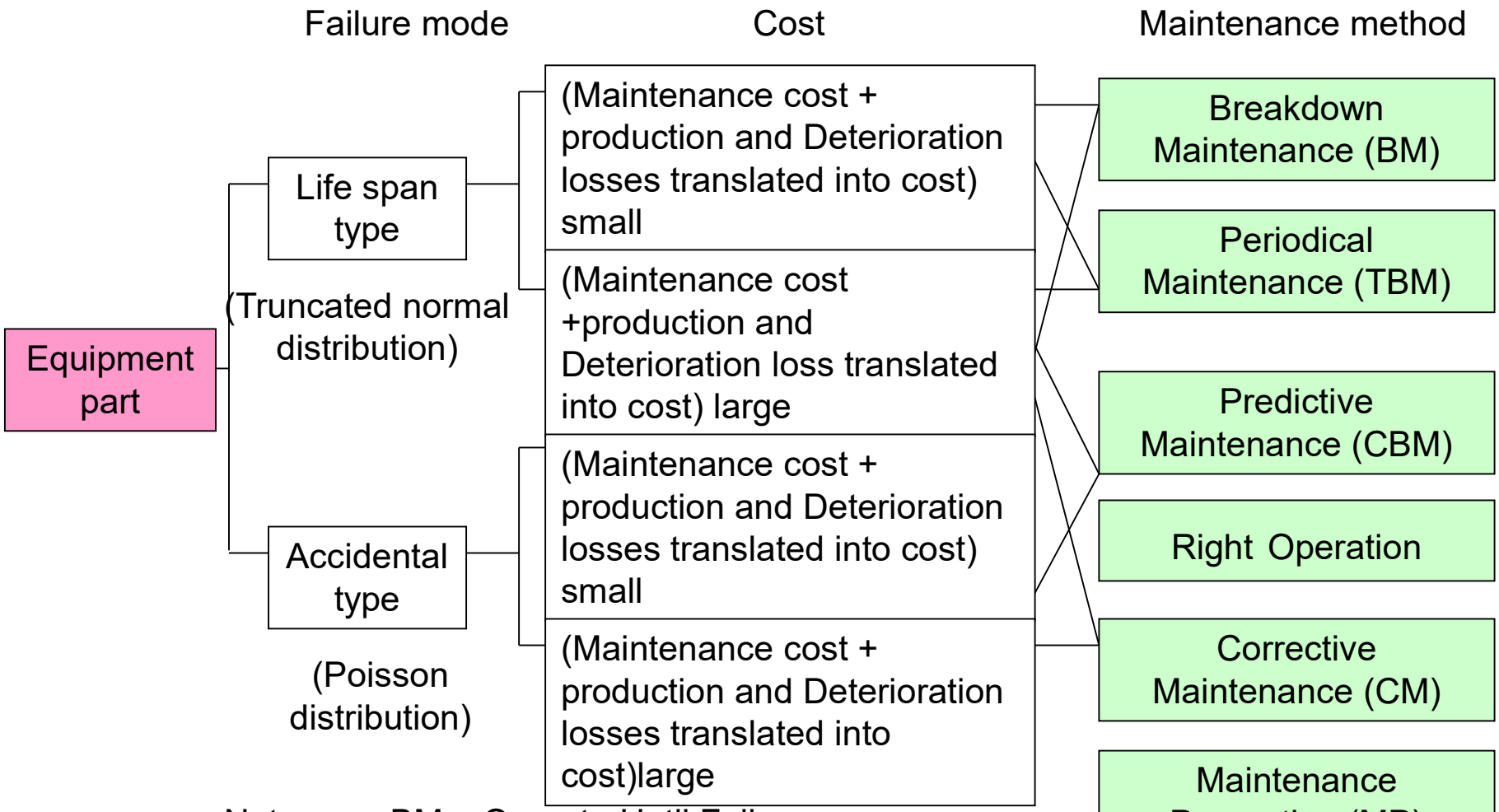
Make maintenance standard

Make maintenance standards based 5W1H questions.

Maintain equipment in a planned way

Maintain equipment based on maintenance standards with the maintenance calendar.

How to Select a Proper Maintenance Based on the Cost



<Notes> BM: Operate Until Failure

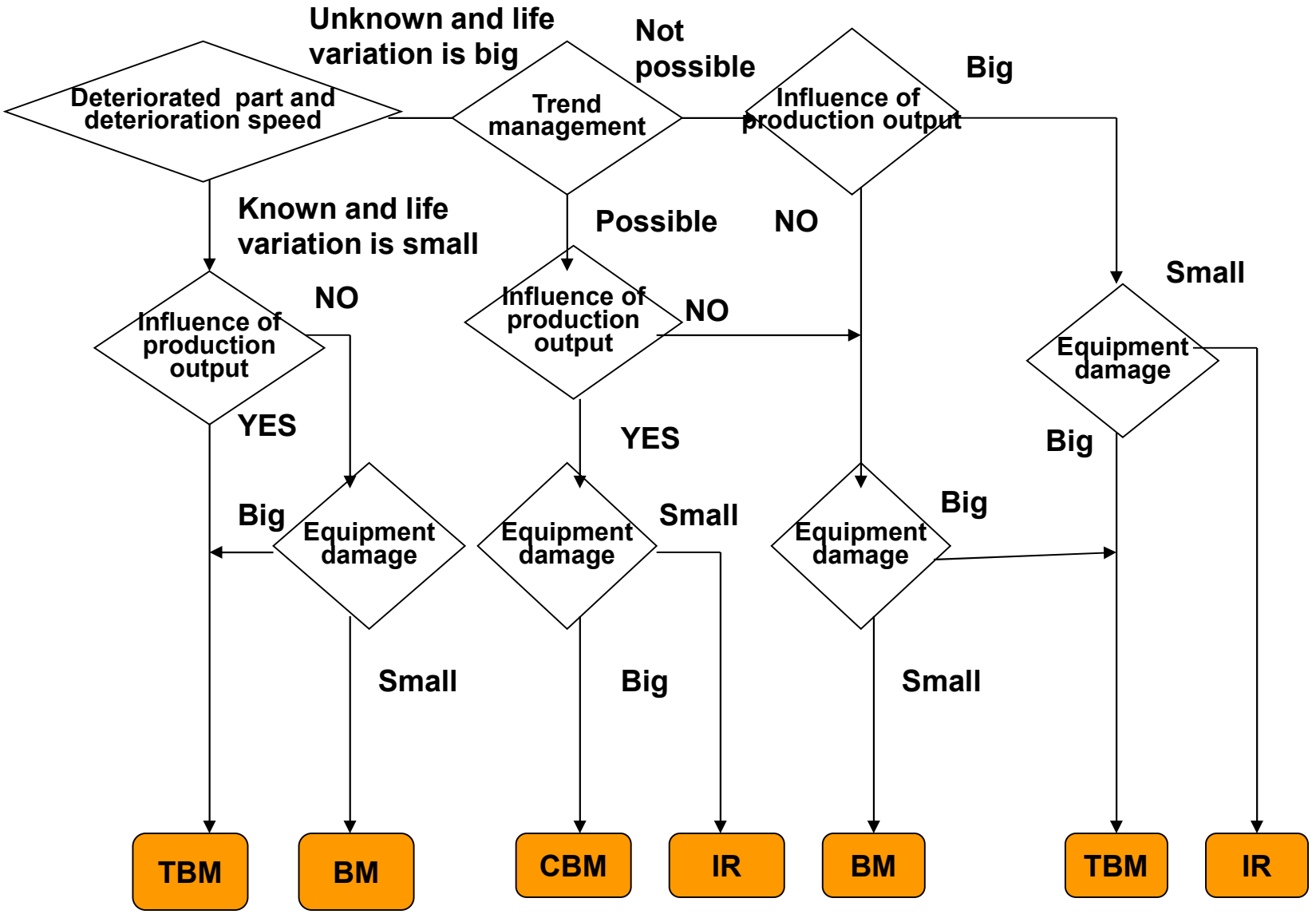
TBM: Time Based Maintenance

CBM: Condition Based Maintenance

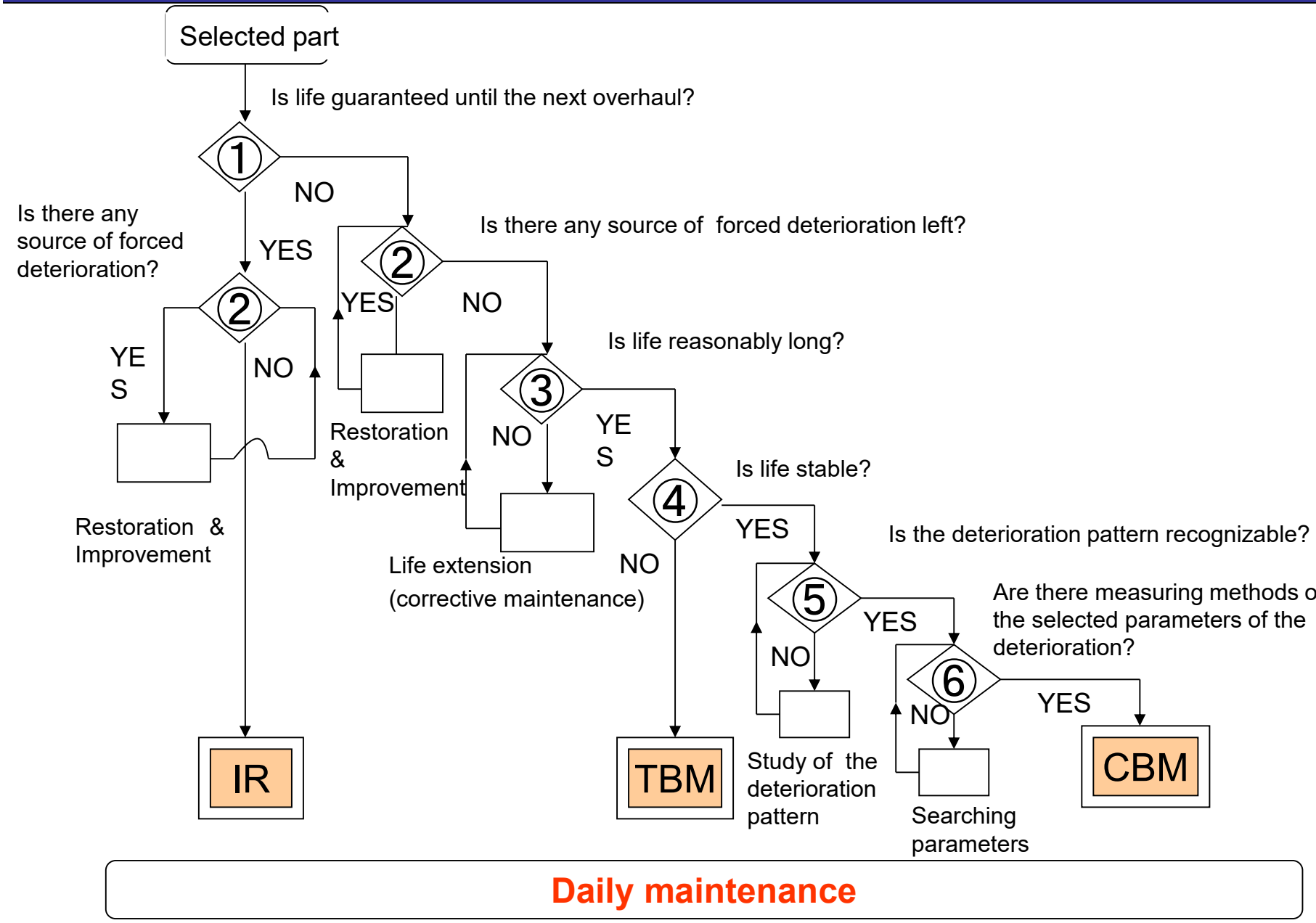
CM: Corrective Maintenance

MP: Design For Maintenance Prevention

Selection by flow chart based on production output, etc.



How to select a proper maintenance based on a technical viewpoint



Equipment Maintenance System

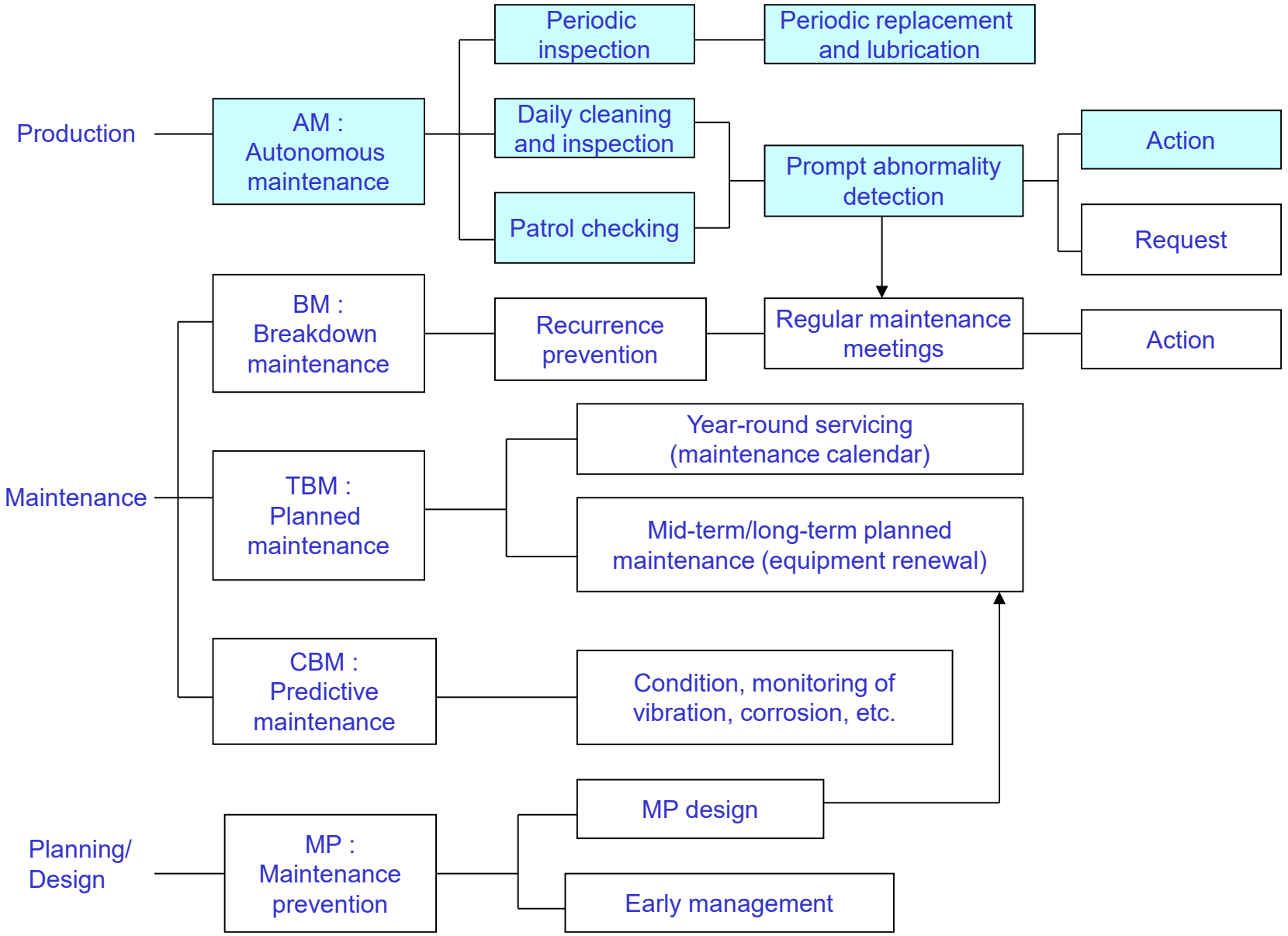


Figure : Maintenance system

Production Department Activities

1.Preventing deterioration:

- Correct operation — preventing human errors
- Correct adjustment — preventing process defect (quality defects)
- Basic housekeeping (establishing basic equipment conditions) — cleaning, lubricating, and tightening
- Early prediction and prompt detection of abnormalities — forestalling failures and accidents
- Keeping maintenance records — feeding back information for recurrence prevention and maintenance–prevention design

Production Department Activities

2.Measuring deterioration:

- Daily inspection — patrol checks and five-senses checks during operation
- Periodic inspection — part of overhaul inspection during plant shutdown or shutdown maintenance

3.Predicting deterioration:

- Minor servicing — emergency measures when abnormal conditions arise and simple parts replacement
- Prompt, accurate reporting of failure and problems
- Assistance with repairing unexpected failures

Maintenance Department Activities

(1)The key player in equipment maintenance

(2)Support for autonomous maintenance

(3)Research and develop new maintenance technologies

(4)Prepare maintenance standards manuals

(5)Build systems for keeping maintenance records, handling maintenance data, and measuring results

(6)Develop and use failure-analysis techniques and implement measures to prevent the recurrence of serious failures

(7)Assist equipment design and development departments (participate in MP design and early equipment management activities)

(8)Control spares, jigs, tools and technical data

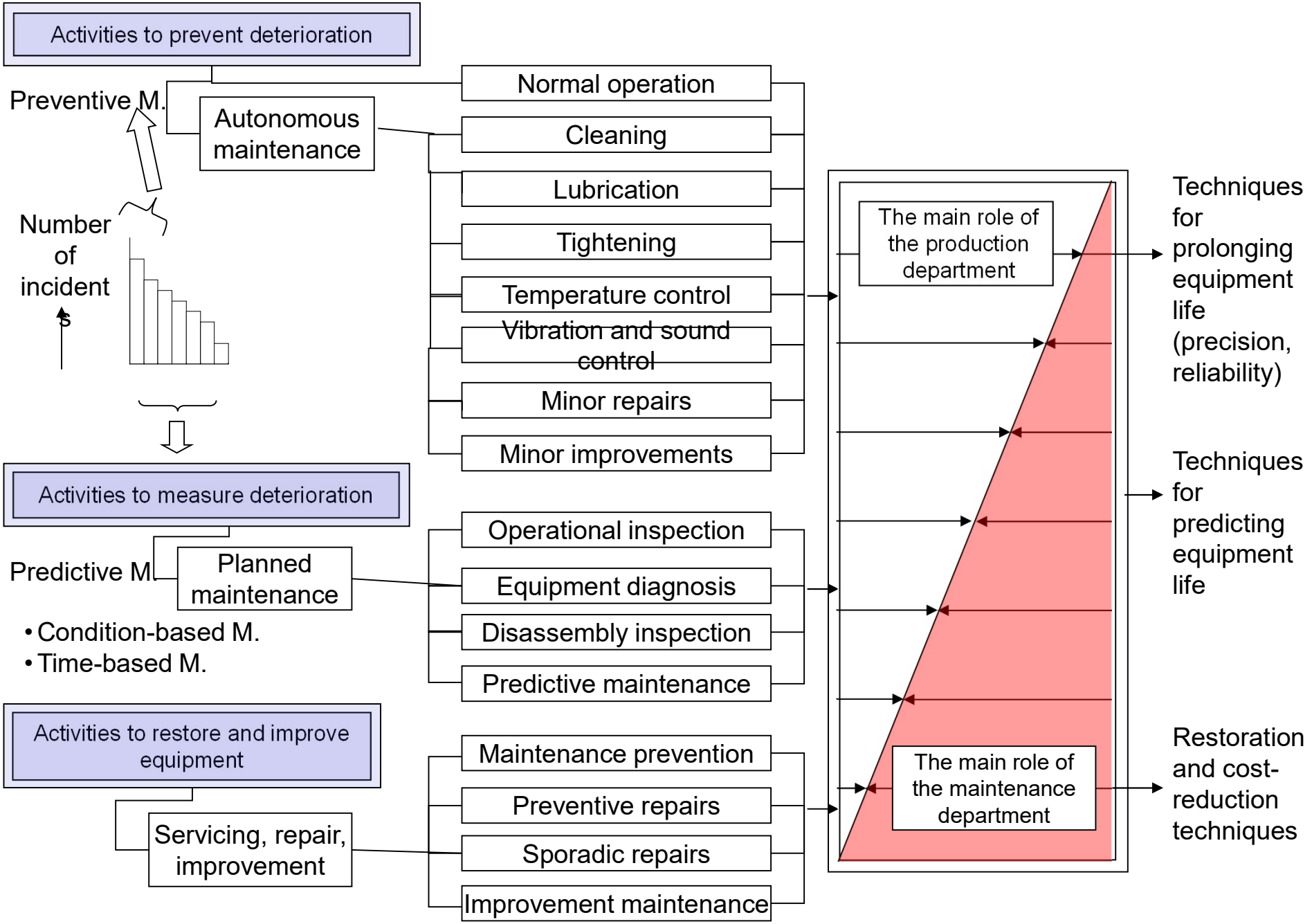
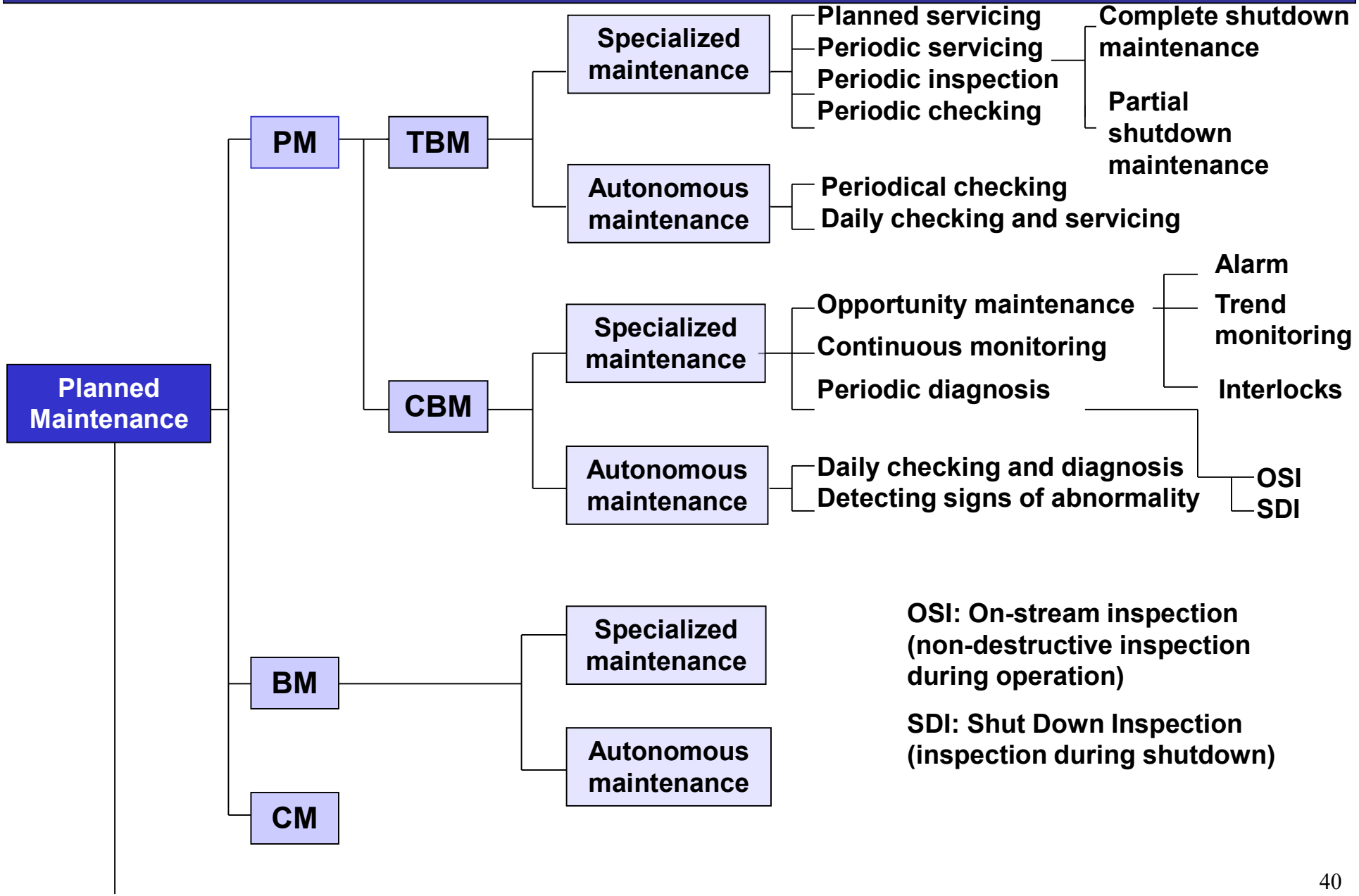


Figure. Share of Maintenance Tasks Between Production and Maintenance

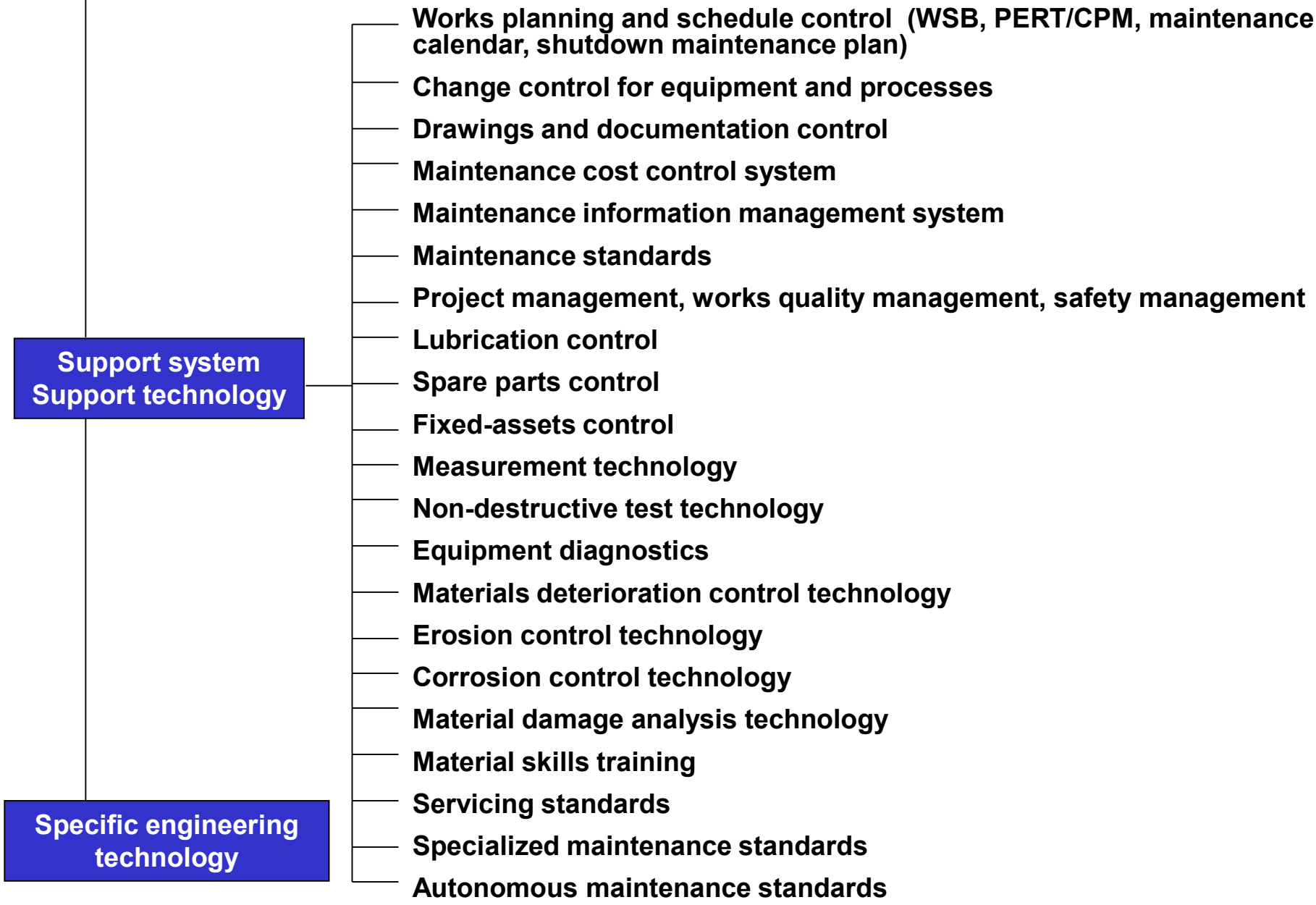
Planned Maintenance System Showing Allocation of Responsibility



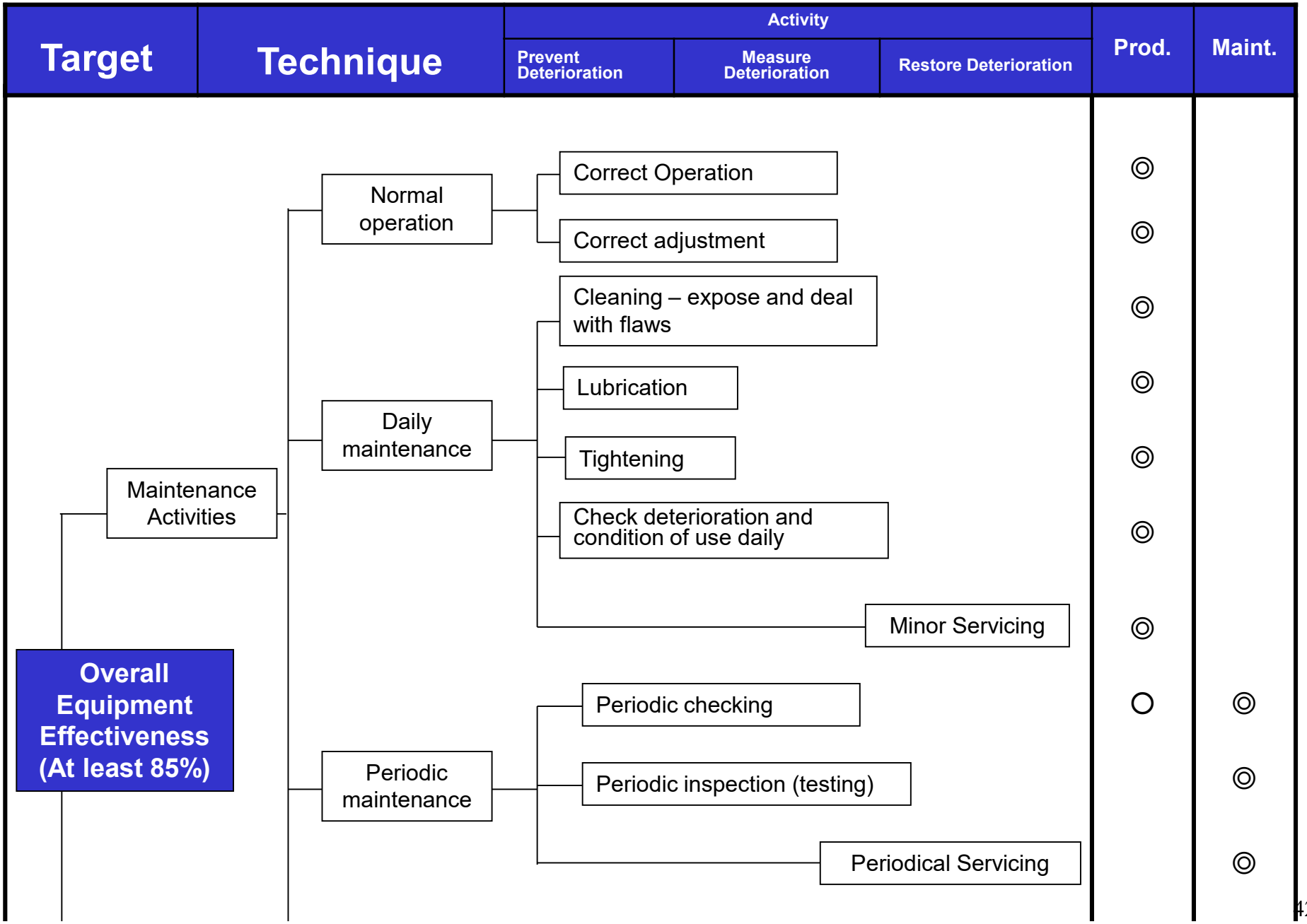
OSI: On-stream inspection (non-destructive inspection during operation)

SDI: Shut Down Inspection (inspection during shutdown)

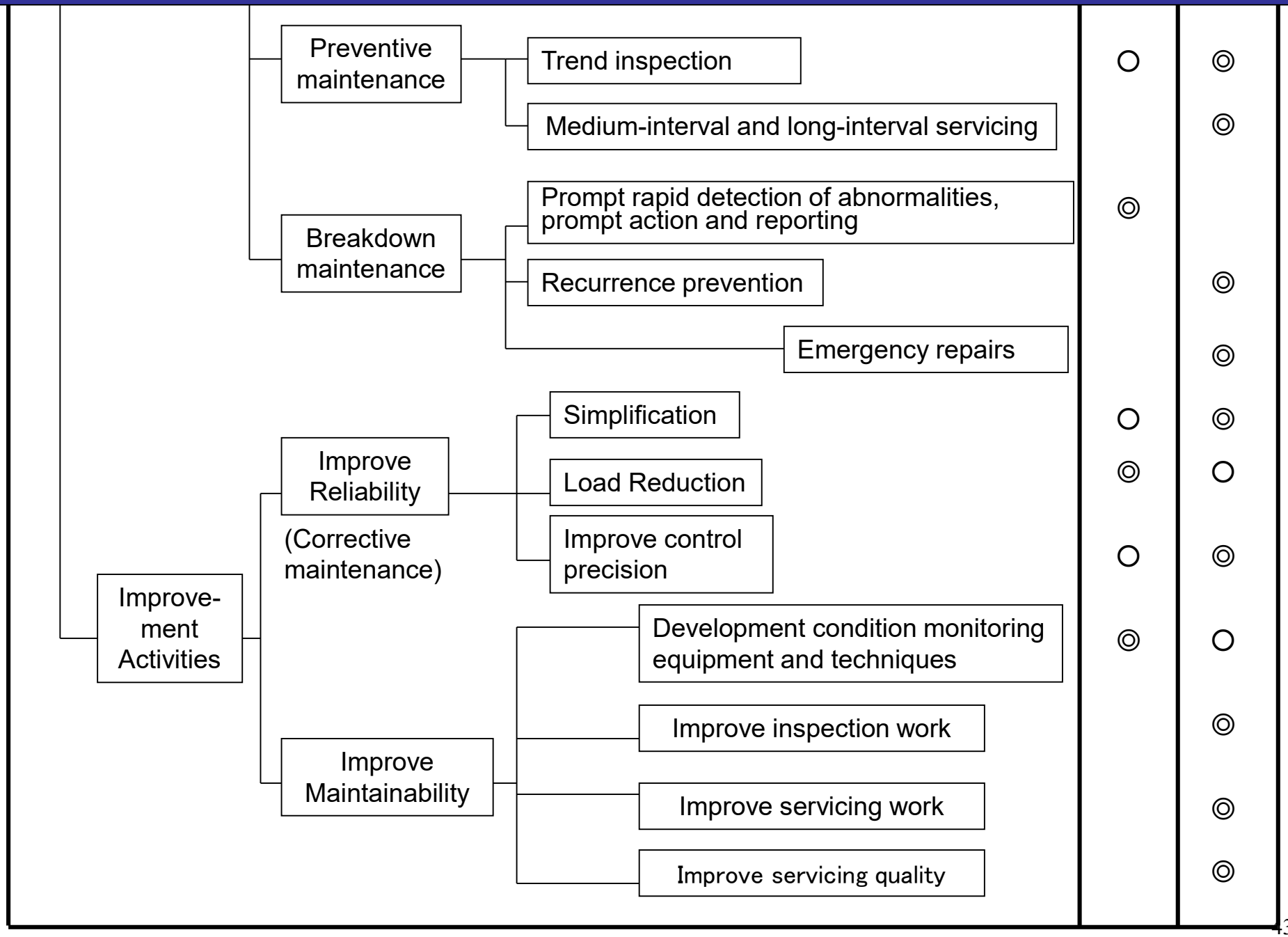
Planned Maintenance System Showing Allocation of Responsibility



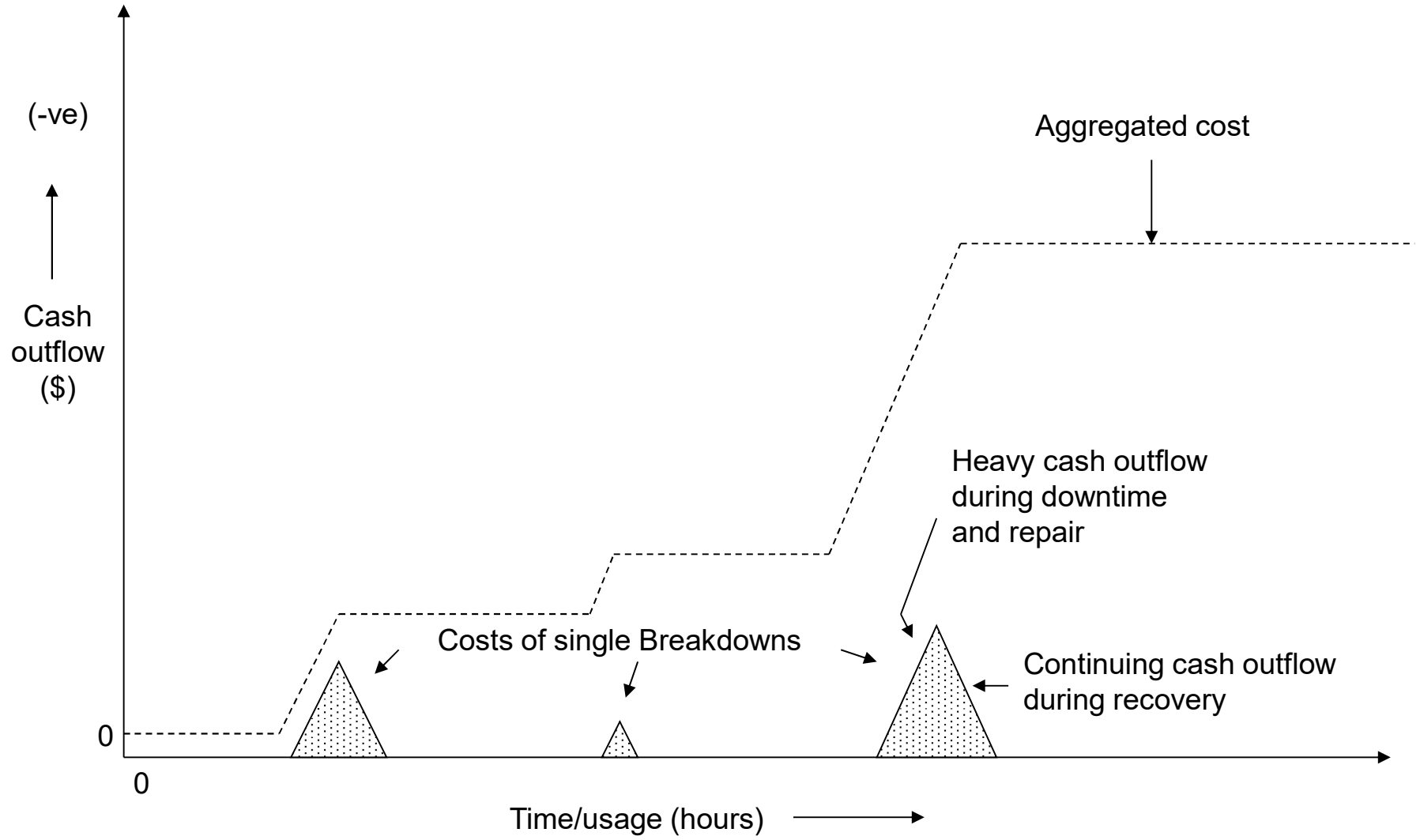
Classification and Allocation of Maintenance Tasks



Classification and Allocation of Maintenance Tasks

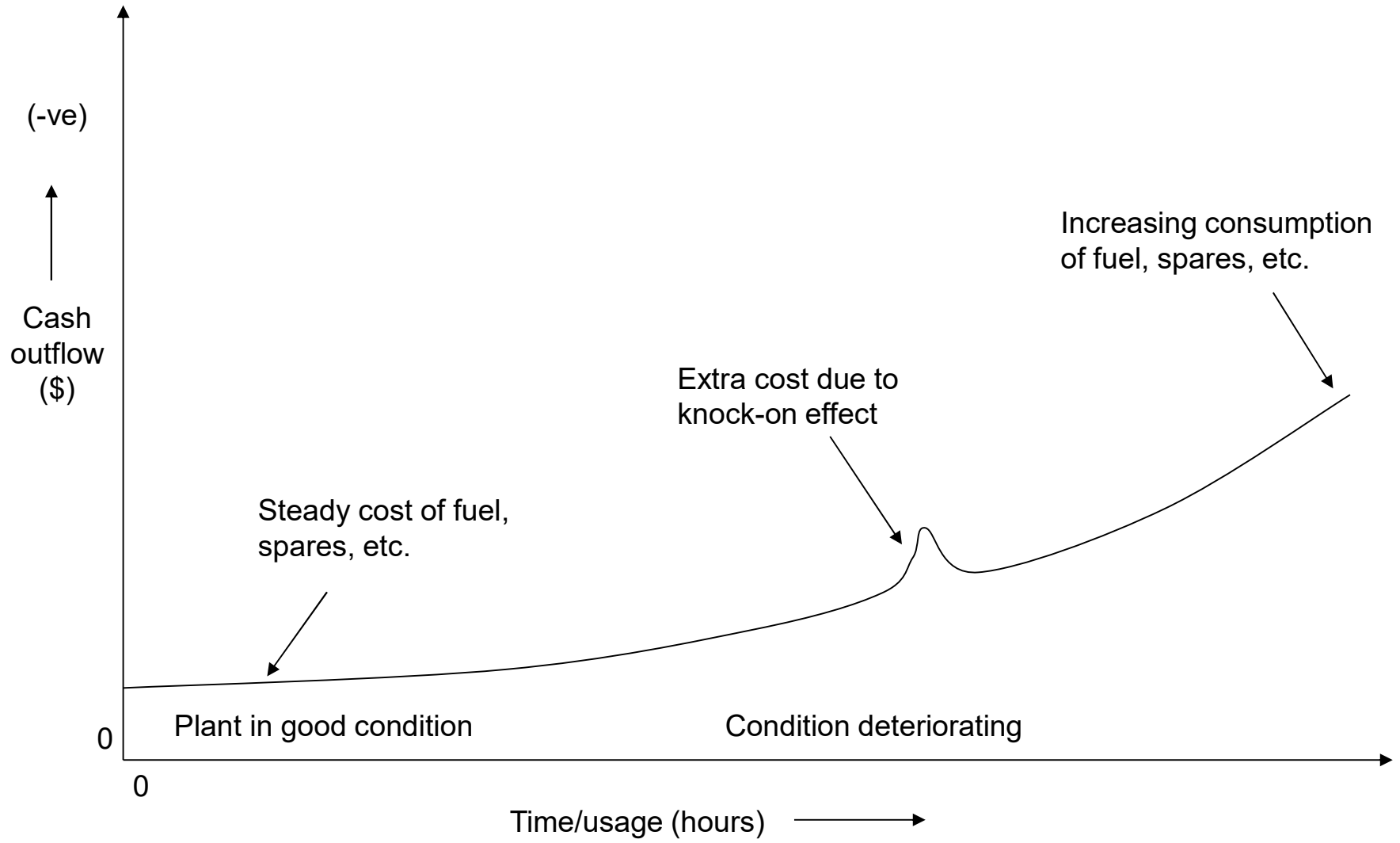


Economic Justification of PM System

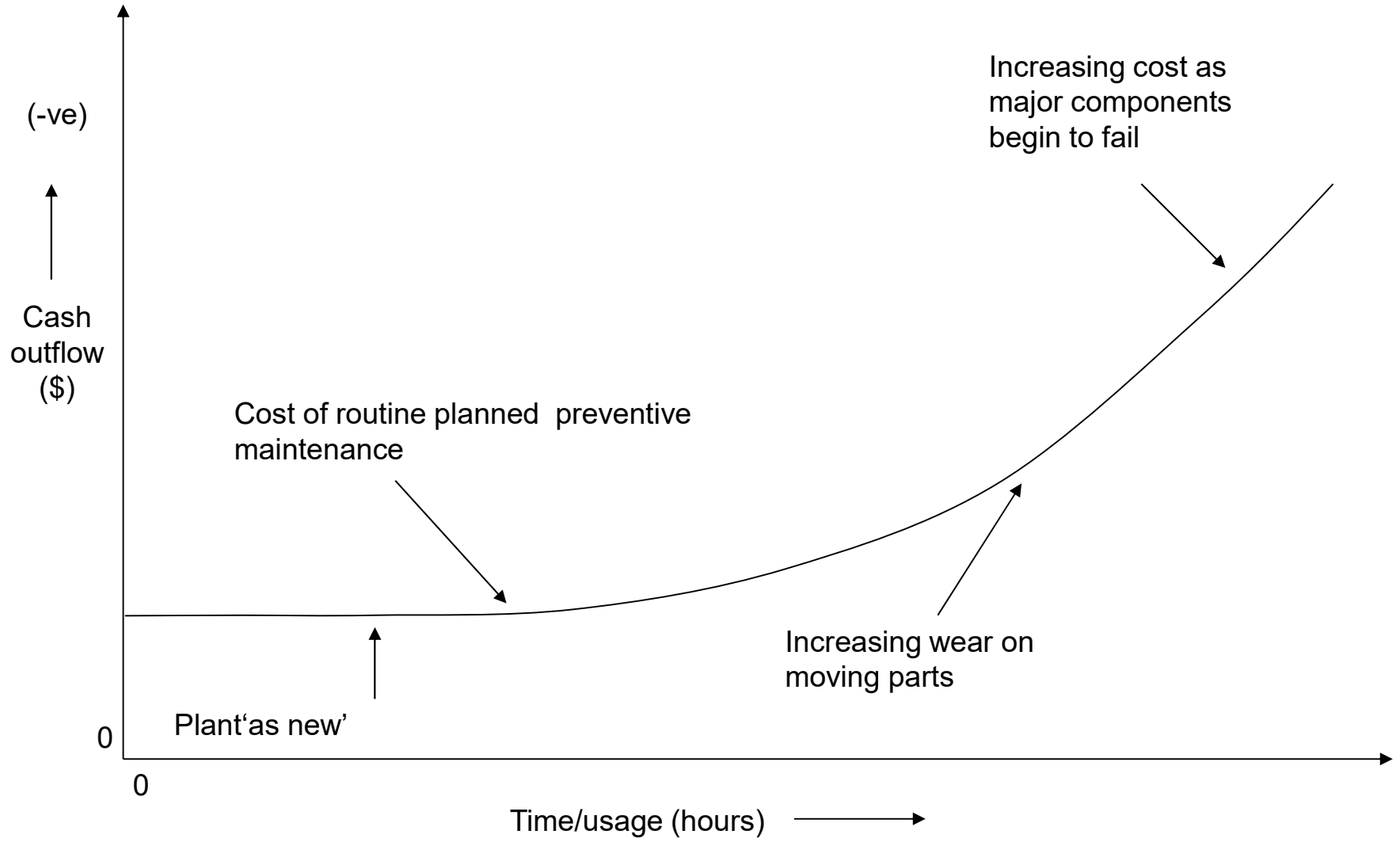


Typical cash flow diagram illustrating the cost of lost production.

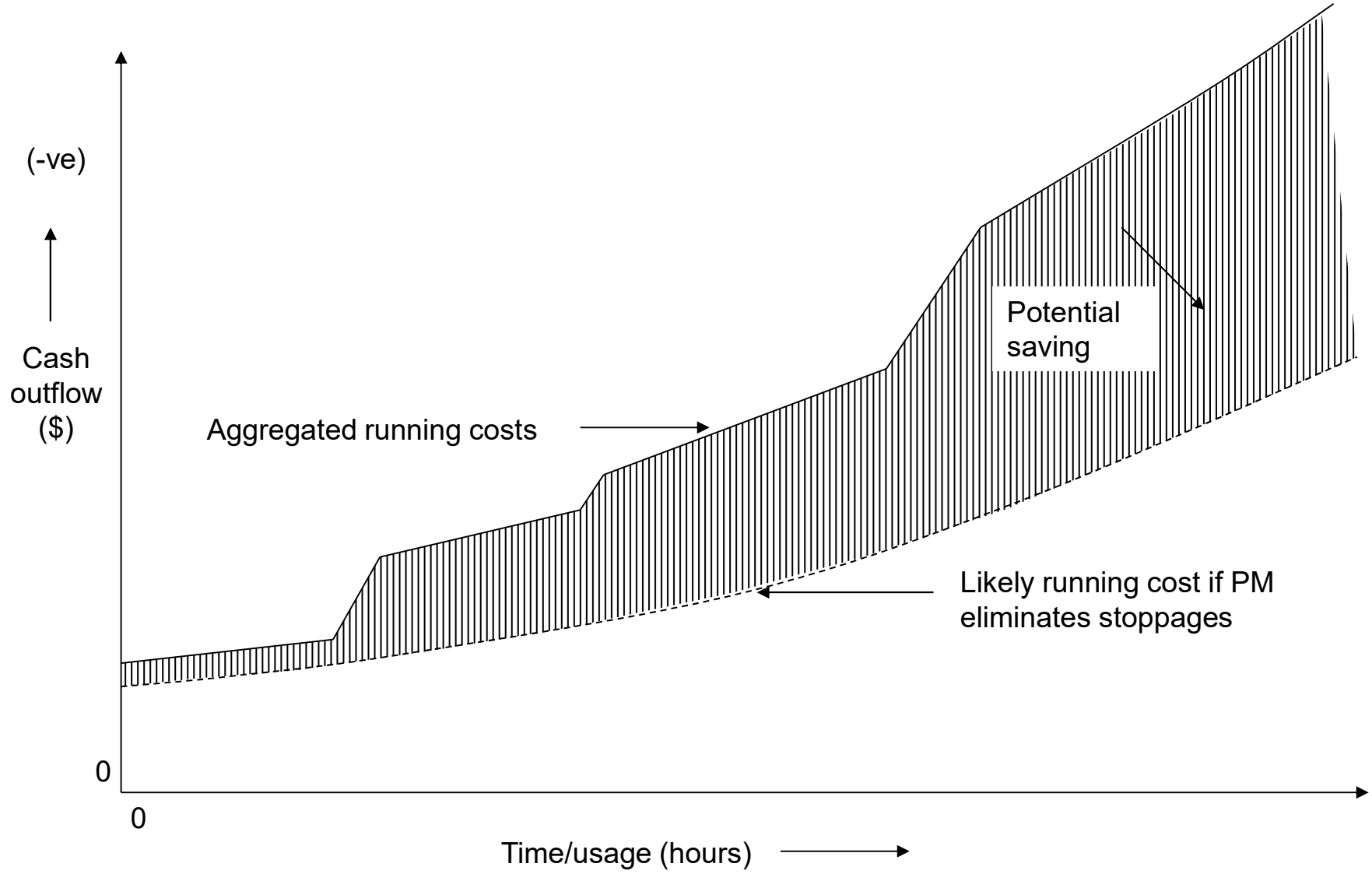
Typical cost of deterioration in plant condition.



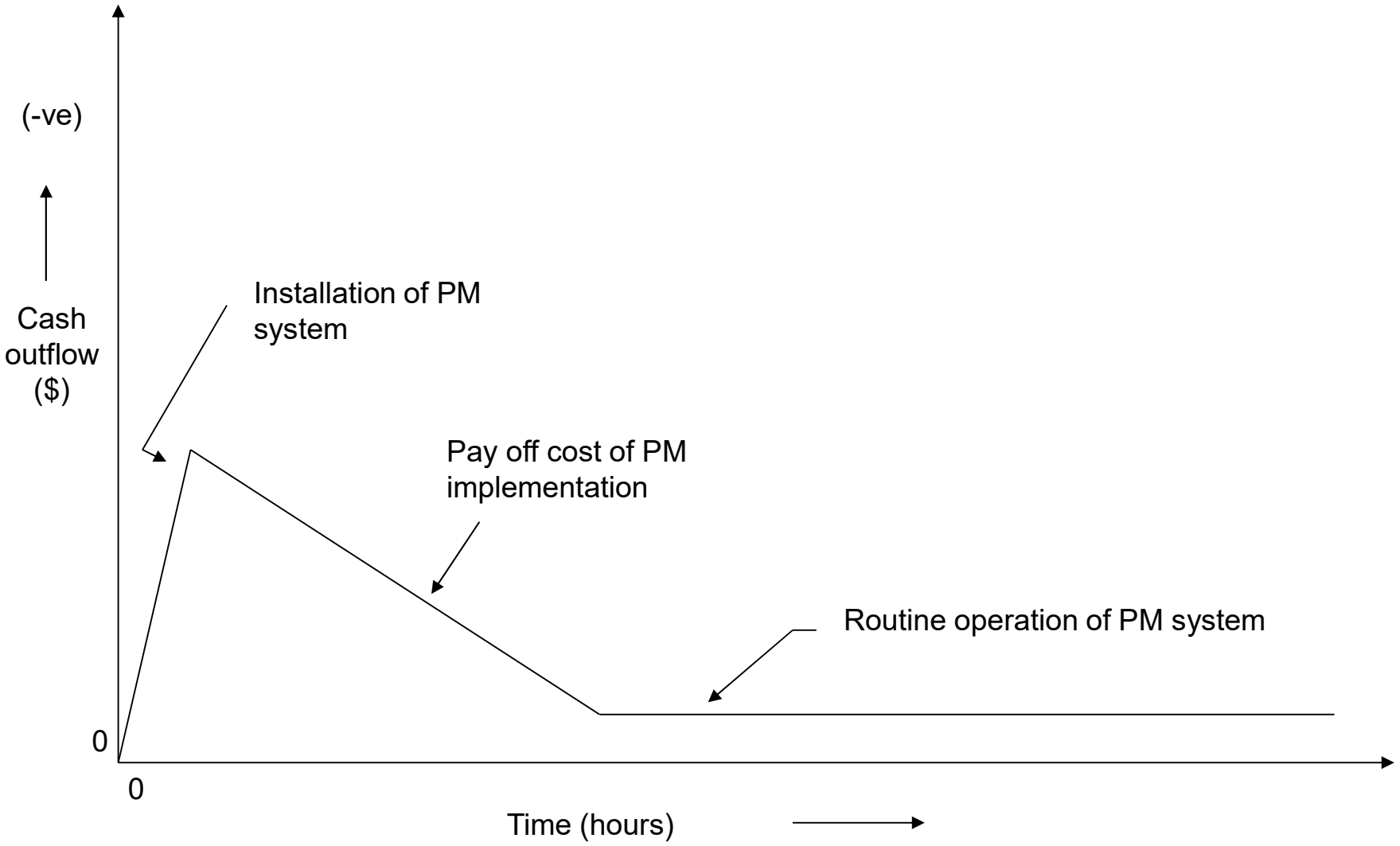
Typical cost of a preventive maintenance strategy.



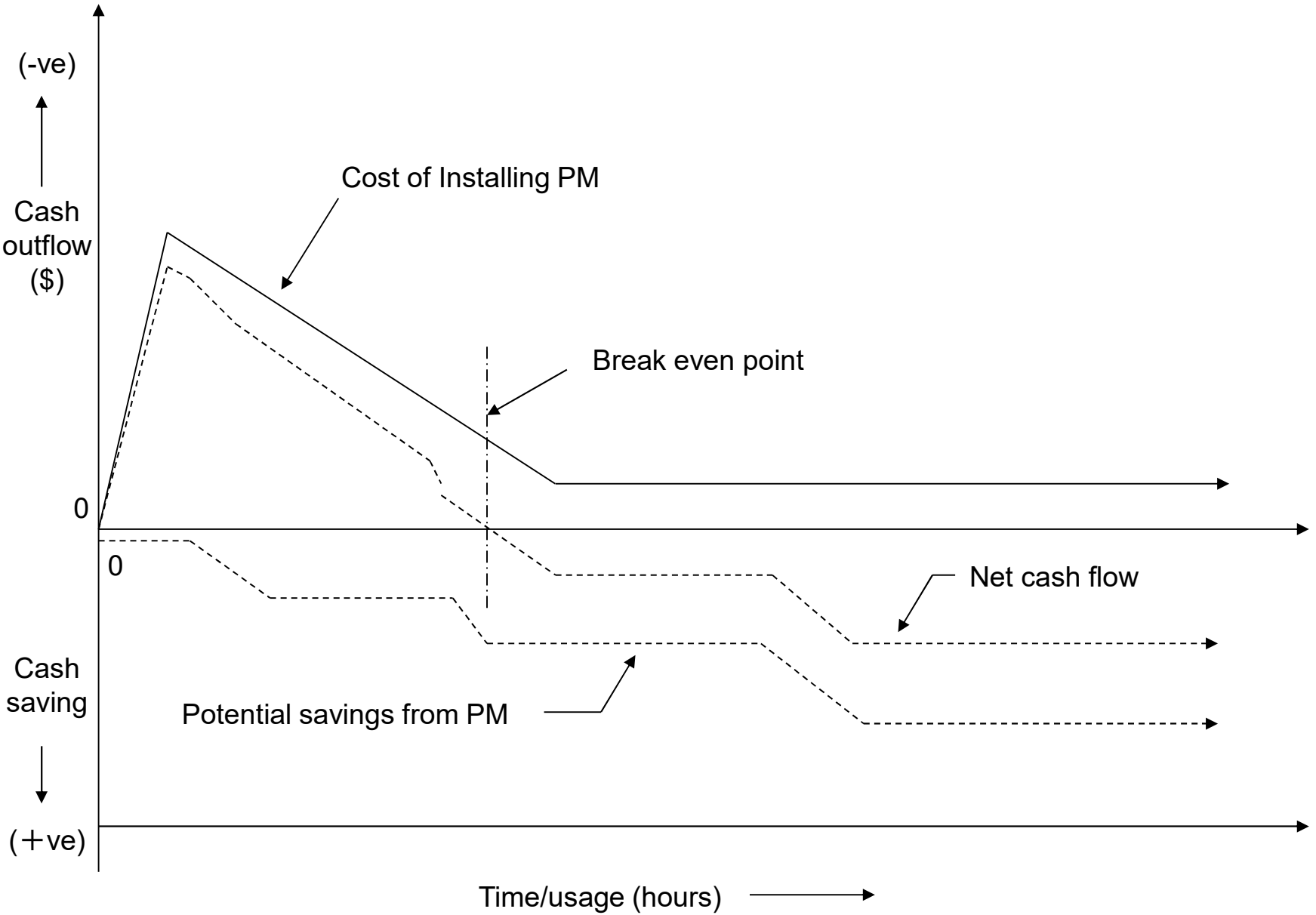
Typical potential savings produced by use of PM monitoring.



Typical cost of TPM implementation.



Typical overall cash flow from an investment in PM.



2. Countermeasures Against Machine Breakdowns

- 2.1 Difference Between Repair and Fix
- 2.2 How to Handle Information of Machine Breakdowns
- 2.3 Following 5G Principle
- 2.4 Breakdown Causes
- 2.5 Breakdown Analysis
- 2.6 Organization

Difference Between Repair and Fix

* “Repair” means to mend in such a way as to eliminate the cause of any trouble and to prevent the recurrence. On the other hand, “fix” means to mend in such a way as to replace the part without pursuing the cause of the trouble. It is often found out that fixing is done in the name of repairing.

* If some part is only fixed, it might cause the same trouble again. So it is important for any worker who is in charge of not only maintenance but also operating the machine, to be aware of the difference between repair and fix.

How to Handle Information of Machine Breakdowns

It is necessary to keep records of the actual results of breakdowns and of the countermeasures. But actually, in spite of the fact that this kind of a job needs much labor, these pieces of information are not being used efficiently.

1 Information on breakdowns must collected just on time

* If the chief of a manufacturing section gets the information on machine breakdowns and the countermeasures for the whole month at one time, it is impossible to expect his machines to operate properly.

* The supervisor must collect information every day, or even every minute in order to take proper measures to prevent machine breakdowns from reoccurring

.

2 The reports on breakdowns and the preventive measures for recurrence must not be received "on the desk".

* Supervisors should receive the information on breakdowns not only by written reports but also by going over to the machine in question and observing the breakdown phenomenon himself.

* However well in details the report is written it does not give the real information unless the person who receives the report sees the actual broken machine.

5 Key Points to Solve the Problems

GEMBA	→	Go to the spot
GEMBUTSU	→	Examine the object
GENGITSU	→	Check facts and figures
GENRI	→	Refer to the theory
GENSOKU	→	Follow the operating standard

Breakdown Causes

① Needing preventive maintenance

② Design deficiency

③ Maintenance operation knowledge

④ Spare parts quality

⑤ Incorrect operation

⑥ Lack of Spare Parts

⑦ Others

Breakdown Analysis

2.5.1 Searching true causes

2.5.2 Development of 5 why's analysis

2.5.3 Development of 5 why's analysis systematically

2.5.4 5 WHY Analysis

2.5.5 Two good examples of 5 why's analysis

2.5.6 Two bad example of 5 why's analysis

2.5.7 Perfect breakdown analysis

2.5.8 Breakdown typology analysis (example)

2.5.9 Pareto diagram of broken components (example)

Searching true causes

*The following preventive measures are often taken:

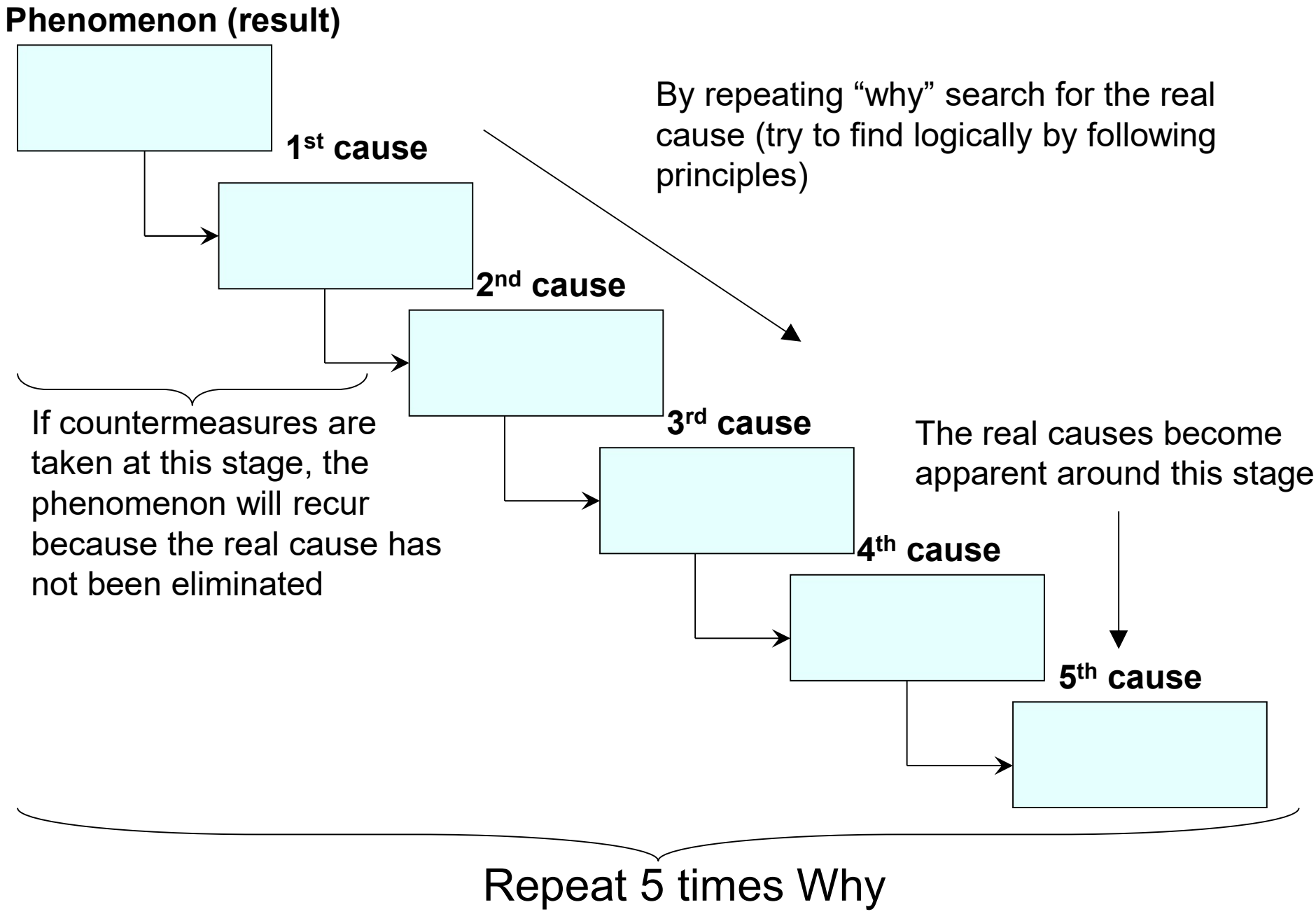
- When the connecting shaft of a machine is broken, the diameter of the shaft is made 30 % larger than the original one.
- The motor was overheated, then its capacity is increased.

⇒These kinds of preventive measures are based on the improper pursuit of causes.

*While other machines are operating with the shaft with 20 mm diameter to increase the diameter to 25 mm only because the shaft started breaking down frequently four or five years after its use is nothing but the result of the lack of investigation.

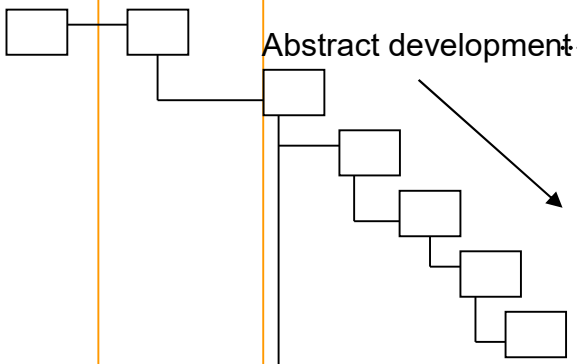
*It is very important especially for pursuing causes that the fact is investigated from the viewpoint of what has been changed and what has gone off the regular operation.

Development of 5 why's analysis (1)



Development of 5 why's analysis (2)

Item	Pheno-mena	Cause	Countermeasures	Influence rate of causes	Evaluation of countermeasures		
					Efficiency	Degree of difficulty	Rapidness



Abstract development

Problems in connection with the system

If there are several causes, it is required to consider the contribution rate of each cause

Concrete development

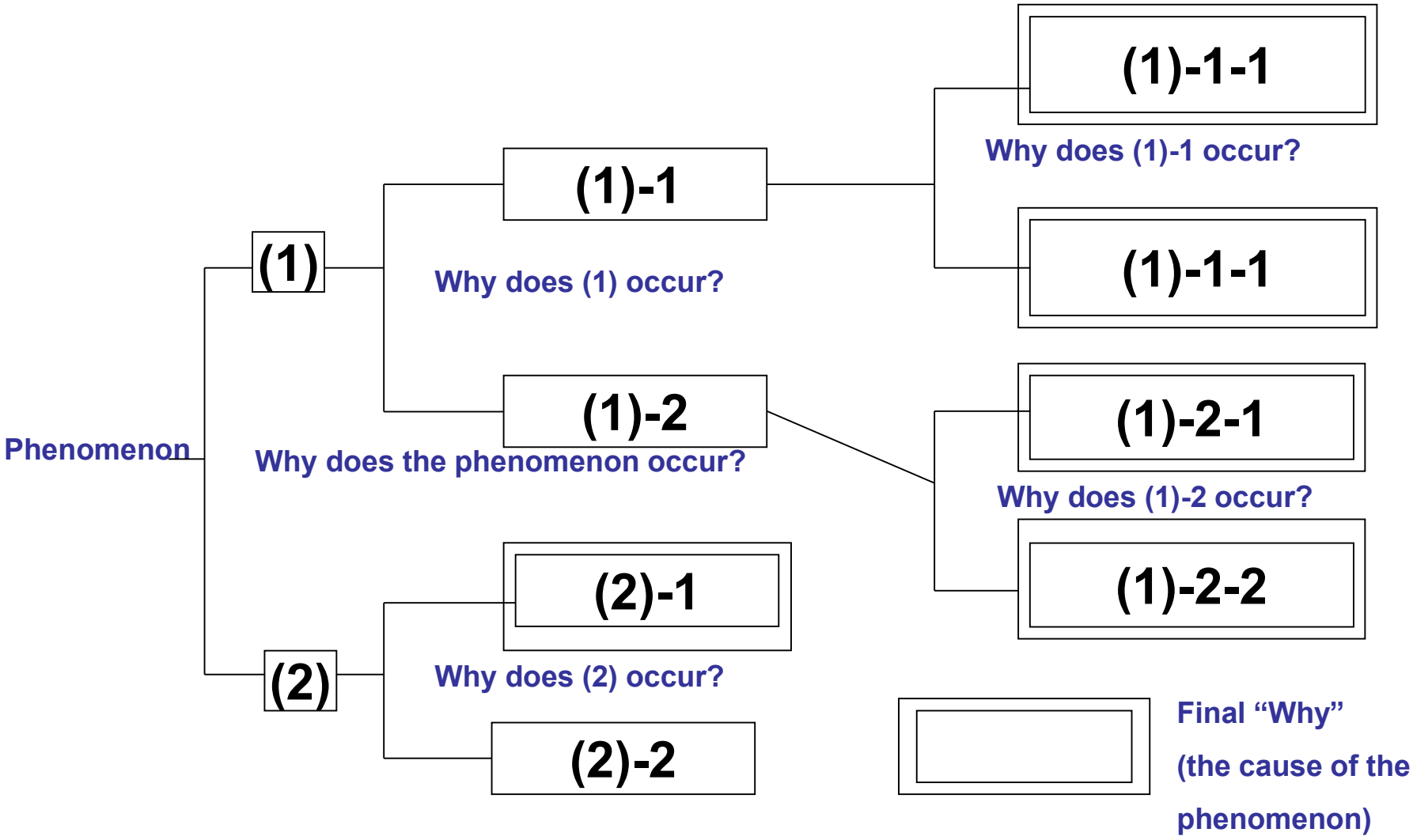
Operational problems

are liable to be highlighted

May come out with many branches

If there are several countermeasures, evaluate all of them properly

Development of 5 why's analysis systematically



5 WHY analysis

1. Grasp the fact — Follow 5G principle

2. Understand structure and function

1) In case of equipment
Draw a sketch of the phenomenon
2) In case of operations
Check the sequence of the operations and points to pay attention and the role of each operation

3. Decide a proper approach of 5 WHY

3-1) Accidental trouble
Approach for the viewpoint of “optimal condition”

3-2) Chronicle trouble
Approach based on the principle and its operating standard

5 WHY analysis

4. Implementation of 5 WHY analysis

4-1) Approach for the viewpoint of the optimal condition
Imagine required conditions and list up the conditions as investigation subjects.
Investigate the listed items with the real objects and analyze only the objects which do not meet required conditions.
4-2) Approach from the viewpoints of the principle and its operating standard
Pay attention to the point which caused the problem and grasp it from the viewpoint of the principle and its operating standard.
Take this problem as first WHY and continue to ask WHY with the object.

5. Checking the investigation method

Against the last cause of “WHY-WHY”, decide a method for investigation and measurement.

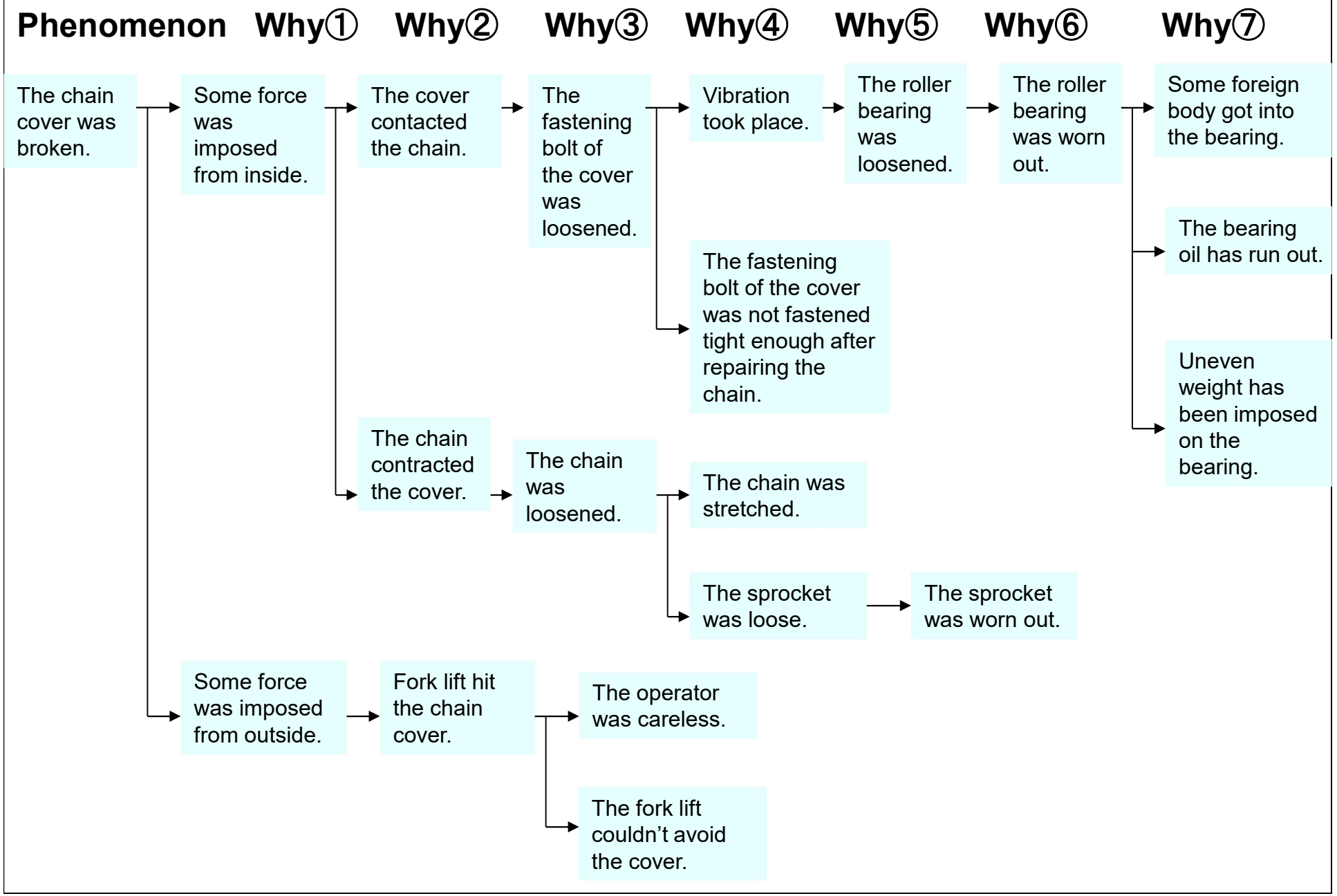
6. Evaluate YES or NO

Evaluate YES or NO by comparing the last cause of “WHY-WHY” and its optimal condition.

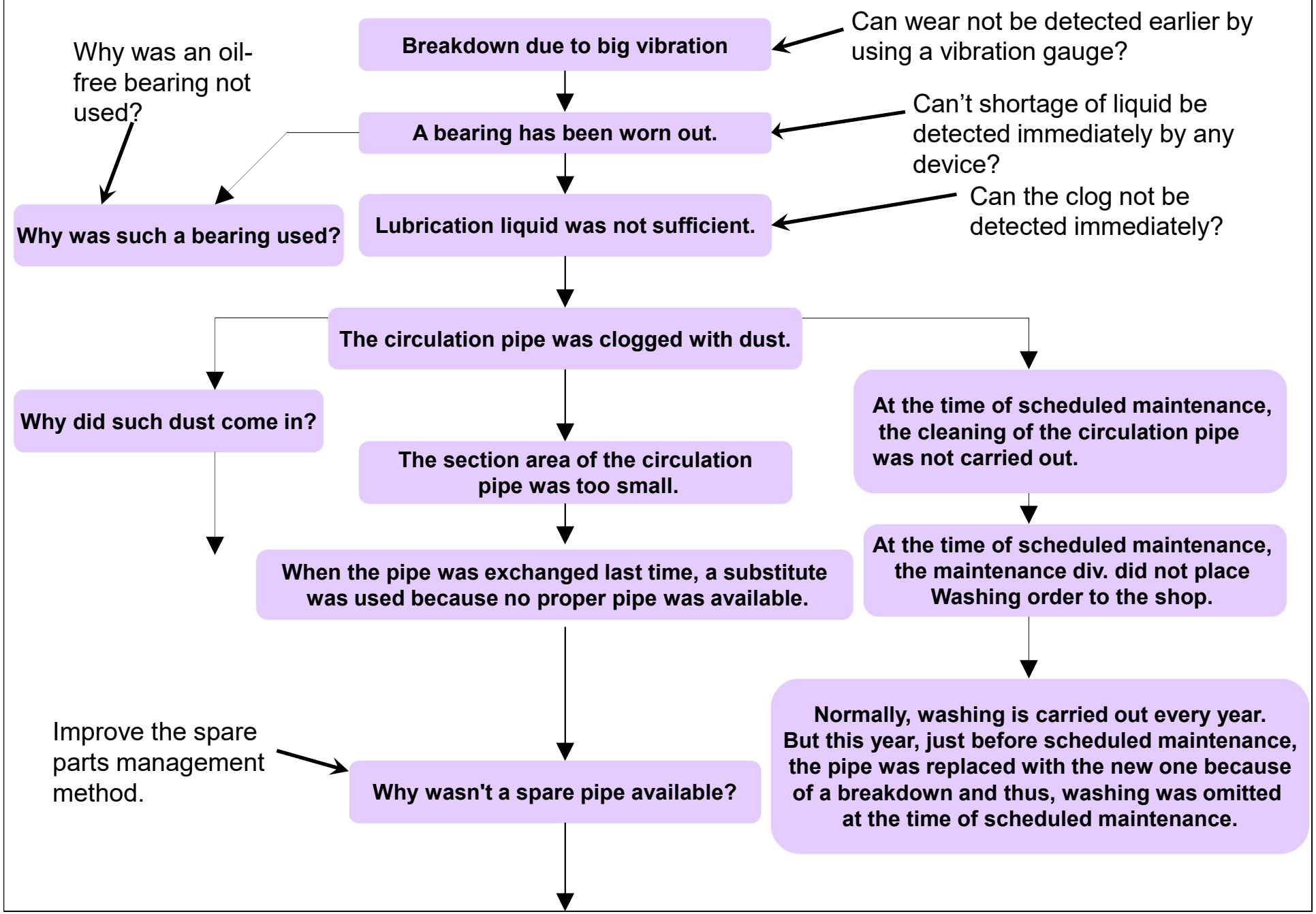
7. Establish a viewpoint plan and implement

For those of NO, establish improvement plans.

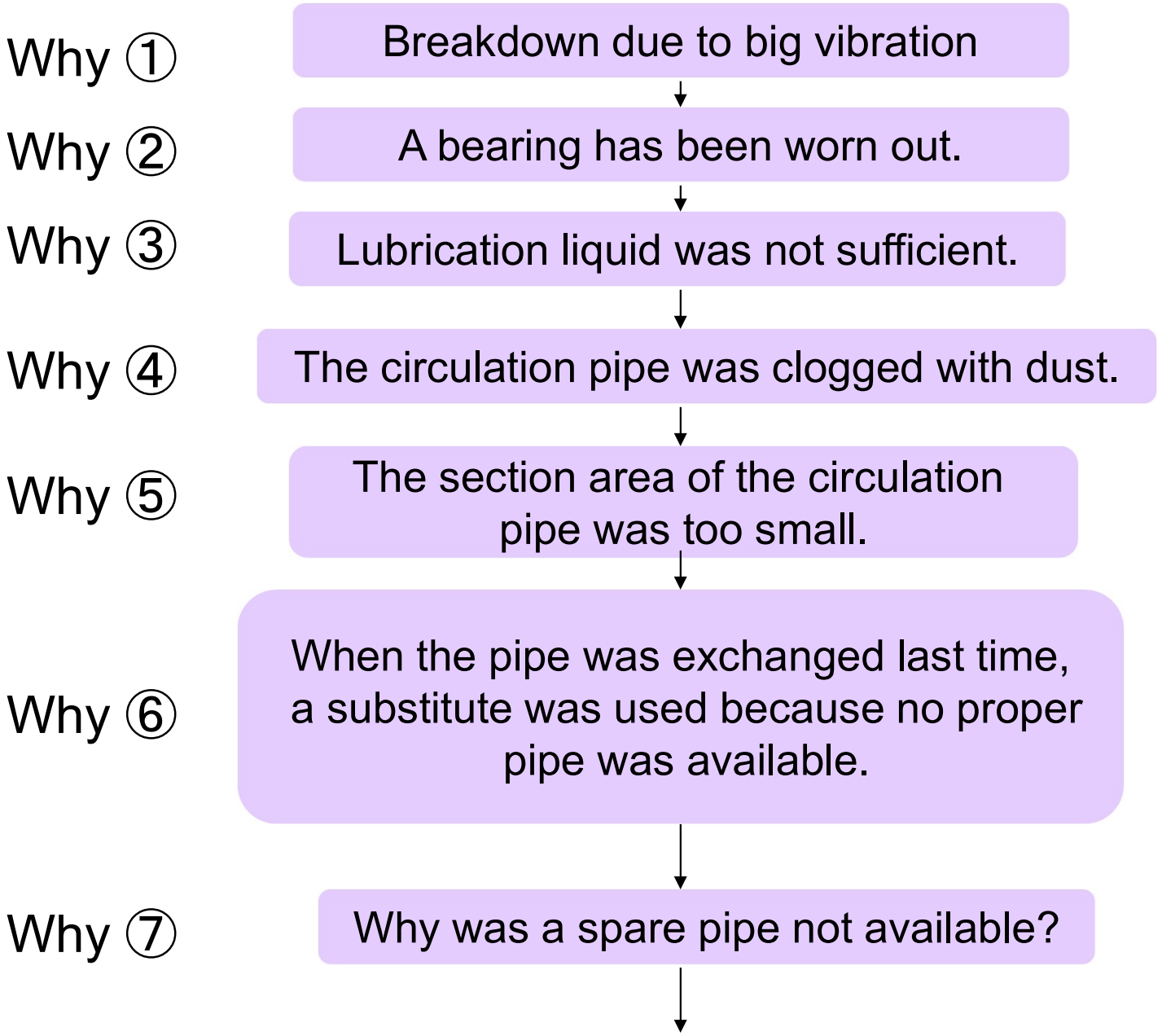
Two good examples of 5 why's analysis (1)

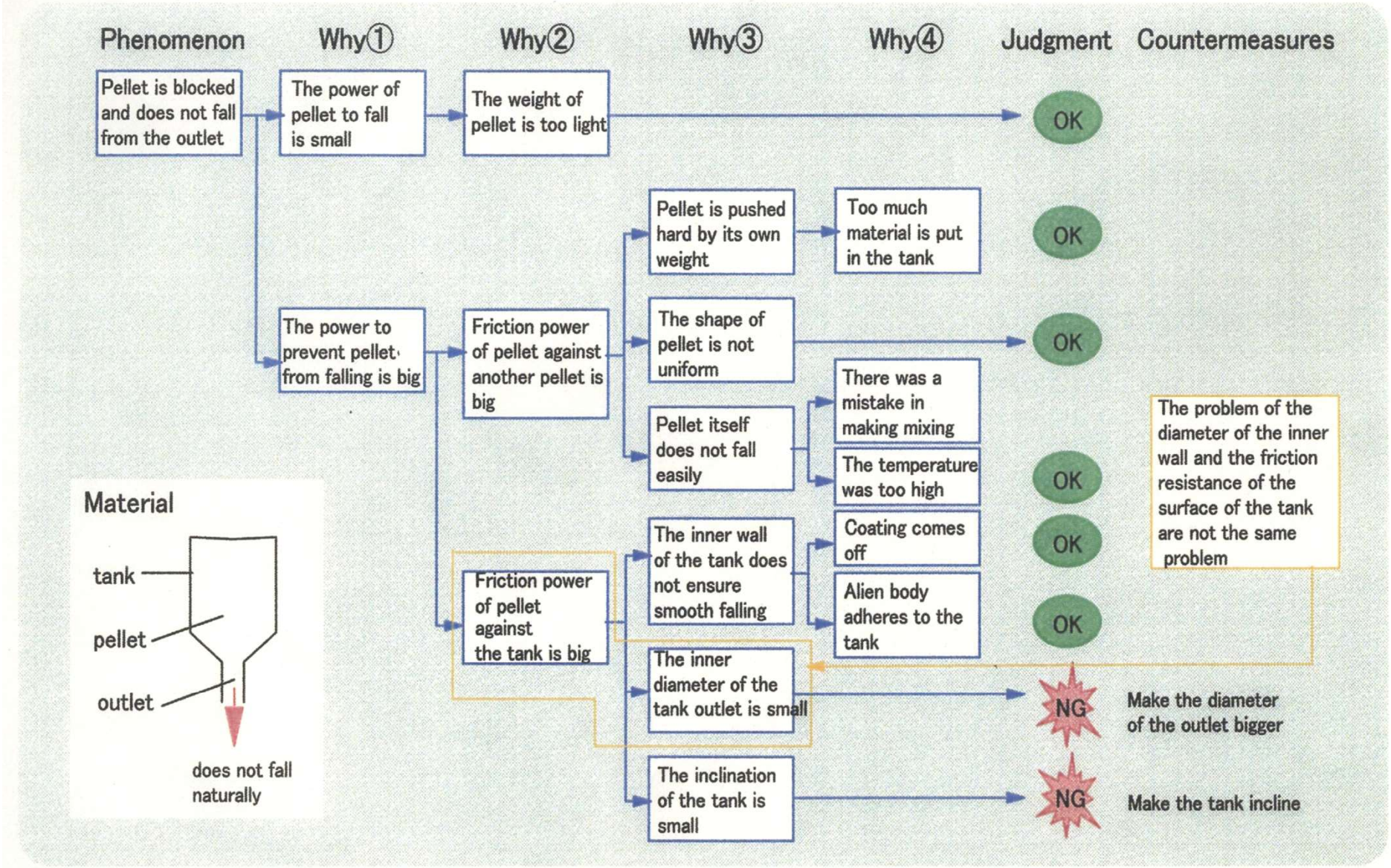


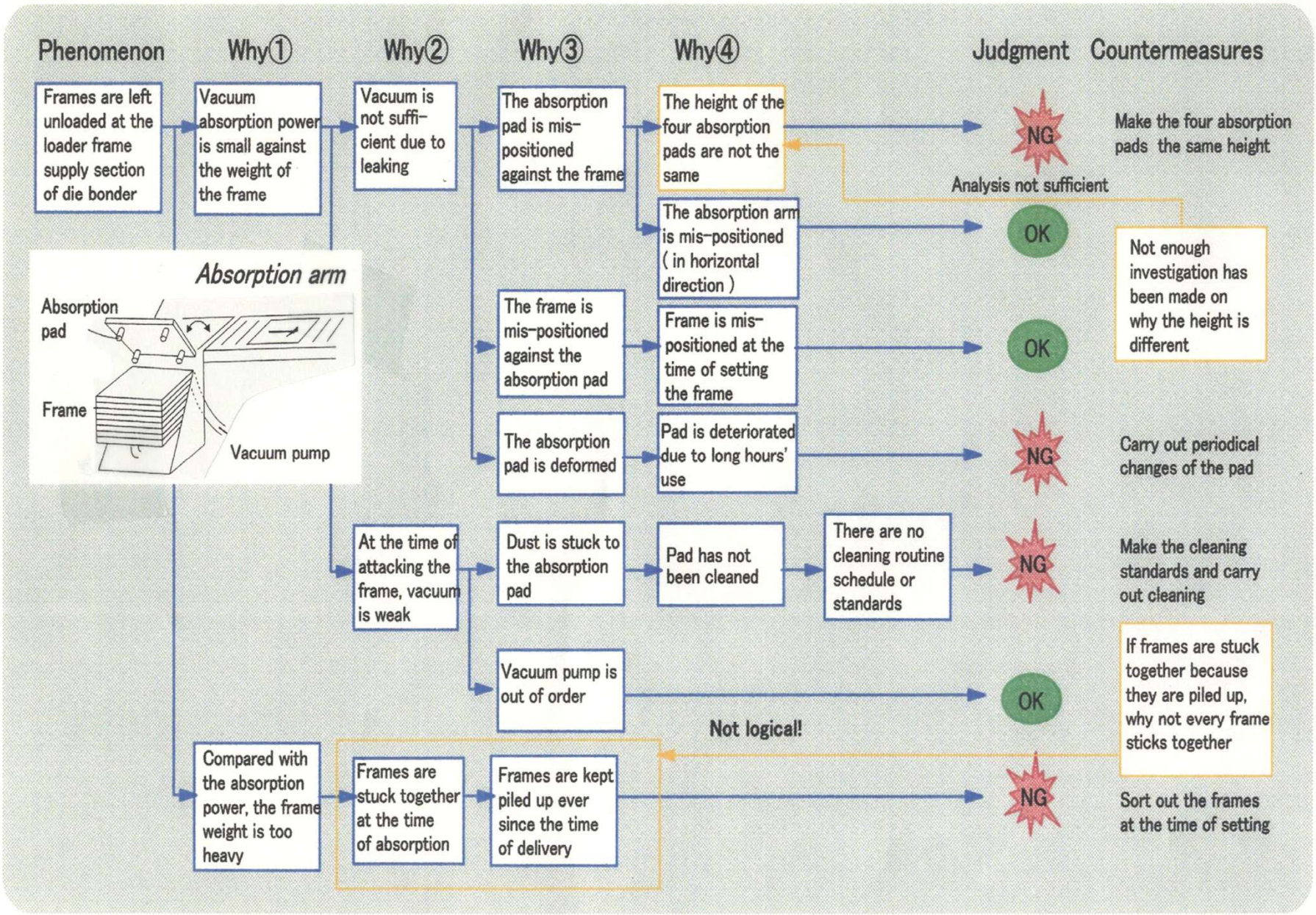
Two good examples of 5 why's analysis (2)



Two bad examples of 5 why's analysis (1)




Phenomenon
Why①
Why②
Why③
Why④
Judgment
Countermeasures
Pellet is blocked and does not fall from the outlet
The power of pellet to fall is small
The weight of pellet is too light
OK
Pellet is pushed hard by its own weight
Too much material is put in the tank
OK
The power to prevent pellet from falling is big
Friction power of pellet against another pellet is big
The shape of pellet is not uniform
OK
Pellet itself does not fall easily
There was a mistake in making mixing
The temperature was too high
OK
The problem of the diameter of the inner wall and the friction resistance of the surface of the tank are not the same problem
Material
tank
pellet
outlet
does not fall naturally
Friction power of pellet against the tank is big
The inner wall of the tank does not ensure smooth falling
Coating comes off
OK
Alien body adheres to the tank
OK
The inner diameter of the tank outlet is small
NG
Make the diameter of the outlet bigger
The inclination of the tank is small
NG
Make the tank incline


Phenomenon
Why①
Why②
Why③
Why④
Judgment
Countermeasures
Frames are left unloaded at the loader frame supply section of die bonder
Vacuum absorption power is small against the weight of the frame
Vacuum is not sufficient due to leaking
The absorption pad is mis-positioned against the frame
The height of the four absorption pads are not the same
NG
Make the four absorption pads the same height
Analysis not sufficient
The absorption arm is mis-positioned (in horizontal direction)
OK
Not enough investigation has been made on why the height is different
Absorption arm
Absorption pad
Frame
Vacuum pump
The frame is mis-positioned against the absorption pad
Frame is mis-positioned at the time of setting the frame
OK
The absorption pad is deformed
Pad is deteriorated due to long hours' use
NG
Carry out periodical changes of the pad
At the time of attacking the frame, vacuum is weak
Dust is stuck to the absorption pad
Pad has not been cleaned
There are no cleaning routine schedule or standards
NG
Make the cleaning standards and carry out cleaning
Vacuum pump is out of order
OK
If frames are stuck together because they are piled up, why not every frame sticks together
Not logical!
Compared with the absorption power, the frame weight is too heavy
Frames are stuck together at the time of absorption
Frames are kept piled up ever since the time of delivery
NG
Sort out the frames at the time of setting

Two bad examples of 5 why's analysis (2)

*When causes are studied in depth, a mistake is liable to take place. For instance,

Trouble: -The motor is overheated.

Causes -

1st cause - *Oil run out.* Why-

2nd cause - *The worker forgot to charge oil.* Why-

3rd cause - *The supervisor did not train the worker well enough.* Why-

4th cause - *The supervisor lacked in his consciousness as a supervisor.* Why-

5th cause - *The supervisor had not been trained enough.* Why-

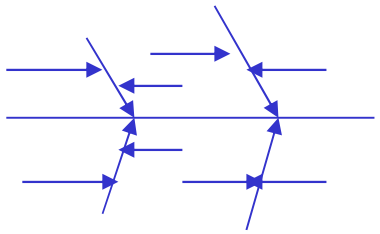
6th cause - *The training policy of the company was not clear.* Why-

・This kind of pursuit of causes only abstracts and expands the range of the problem and forgets about the reality. Anyone may fall into the same kind of a mistake if he does not grasp the real problem by proper observation.

Perfect breakdown analysis (1)

1. Why did the equipment break down?
2. Why did that very part of the equipment break down?
3. What stress was applied to the part?
4. Why was that stress applied to the part?
5. What is required to prevent the failure?
6. Who should take care of preventing failure recurrence? When? How?
7. Were there any symptoms before the failure occurred?
8. Does the failure show visible symptoms?
9. What symptoms may anticipate the failure?
10. Can the failure be prevented by analyzing its symptoms?
11. How can the symptoms be detected?
12. What type of expertise and skills should the operator have to detect the failure?

Perfect breakdown analysis (2)



1	Which part of the machine broke down?
2	How did it break down?
3	Why did that very part of the machine break down?

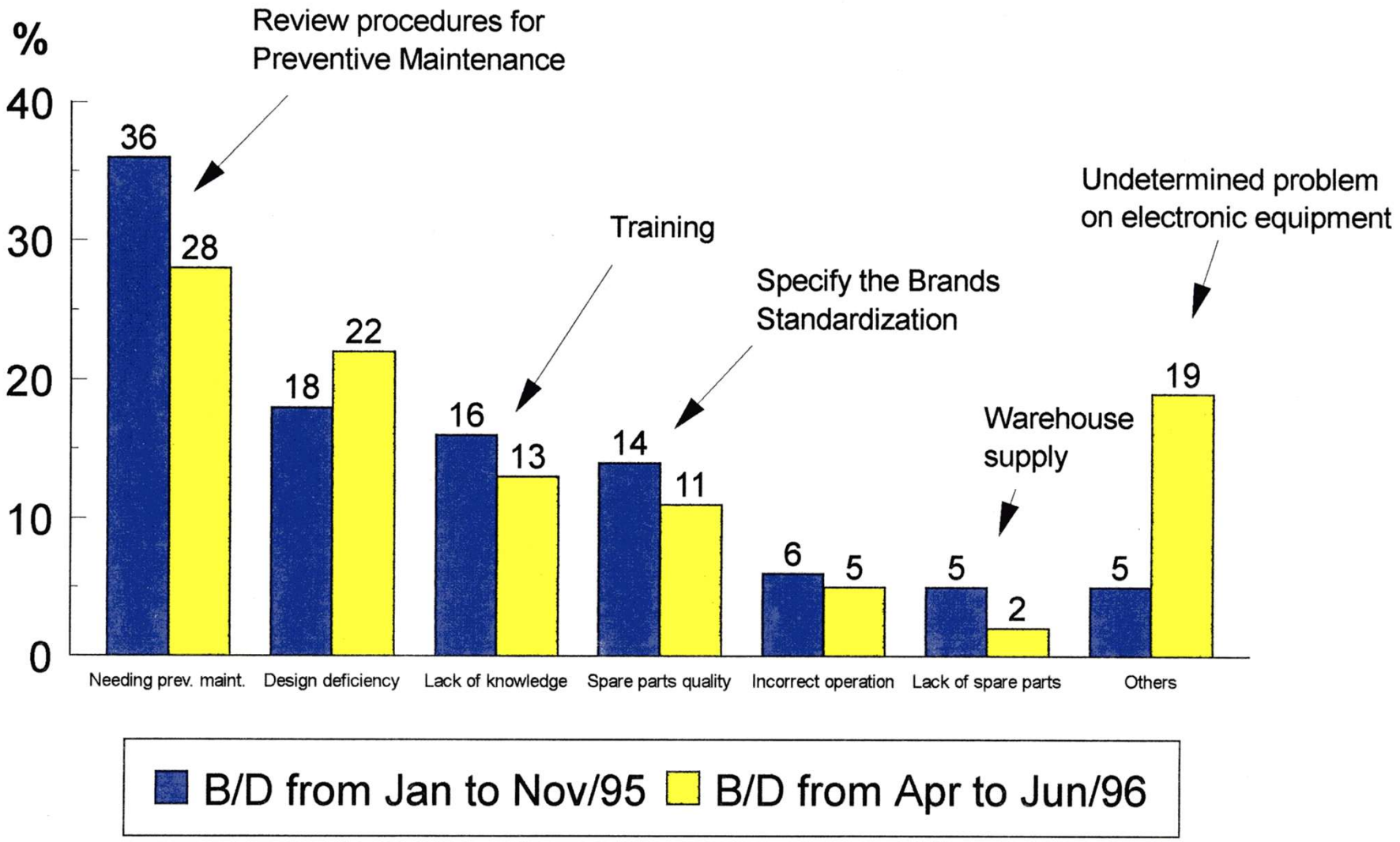
Sketch of the machine/part

4.1	Why	4.2	Why	4.3	Why	…	. . . . .

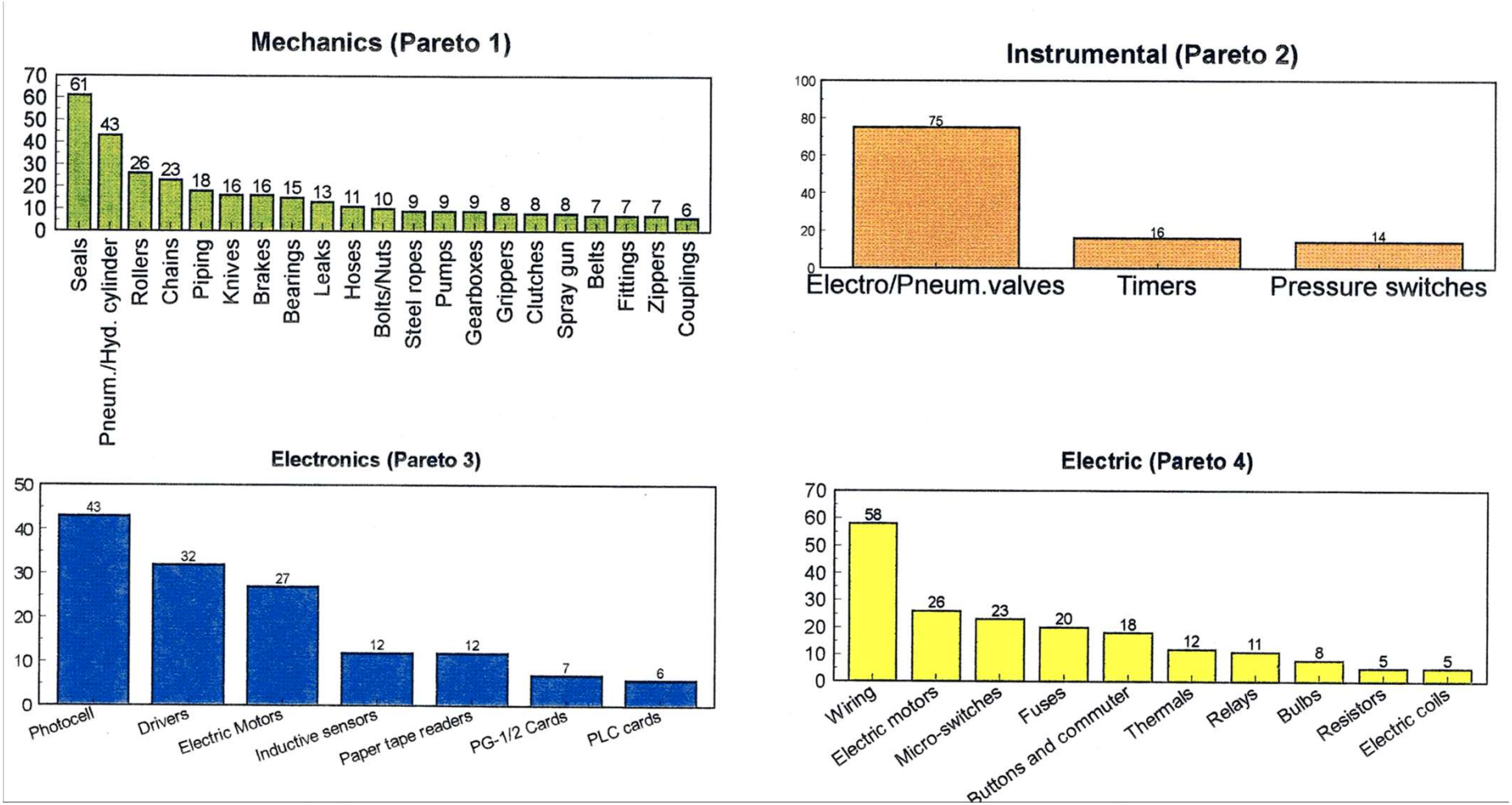
5	What symptom may anticipate the breakdown?
6	Actions to eliminate the breakdown

7.1	Actions to prevent the break down	7.2	Why	7.3	When	7.4	How	7.5	Skills required

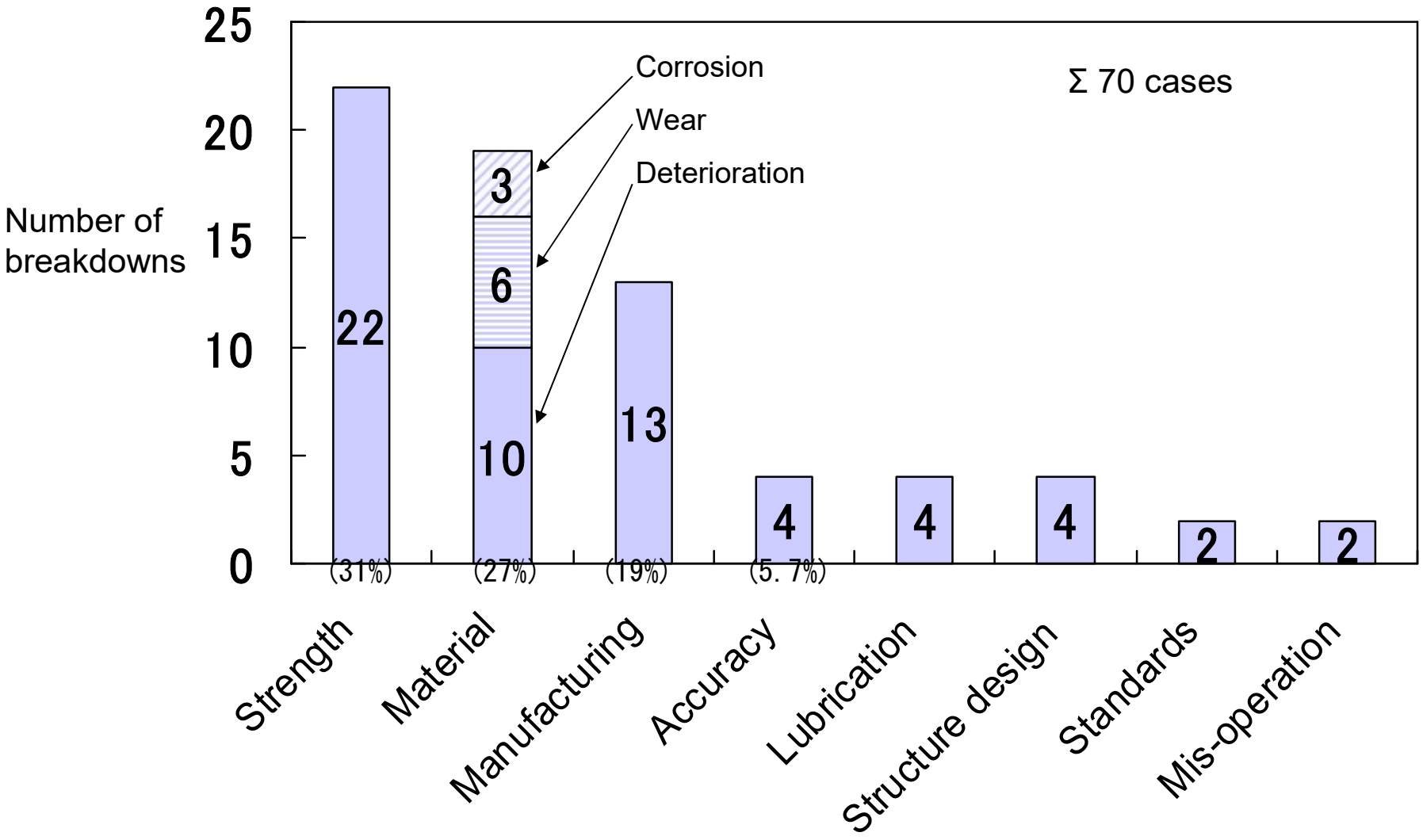
Breakdown typology analysis (example)



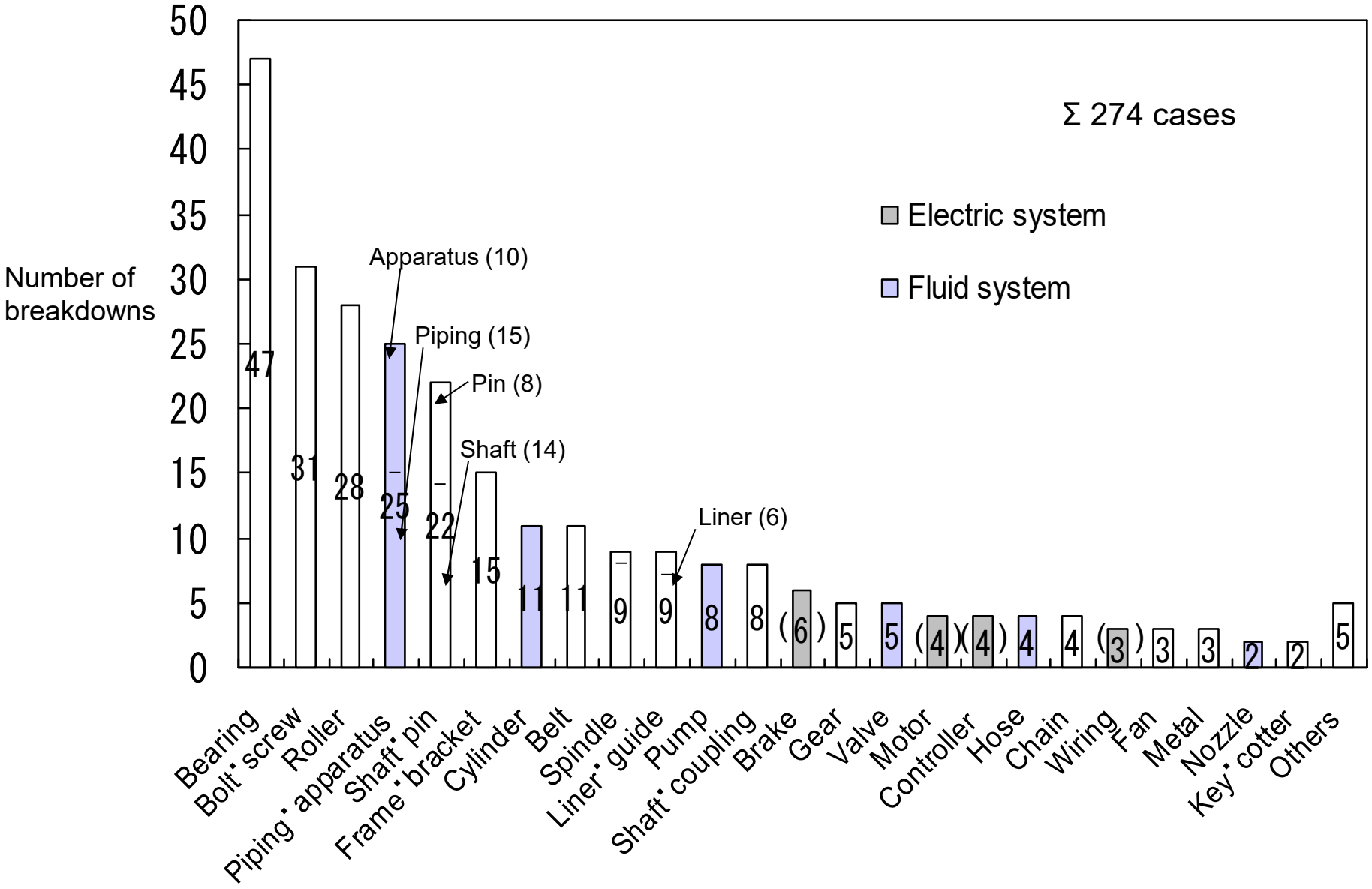
Pareto diagram of broken components (example)



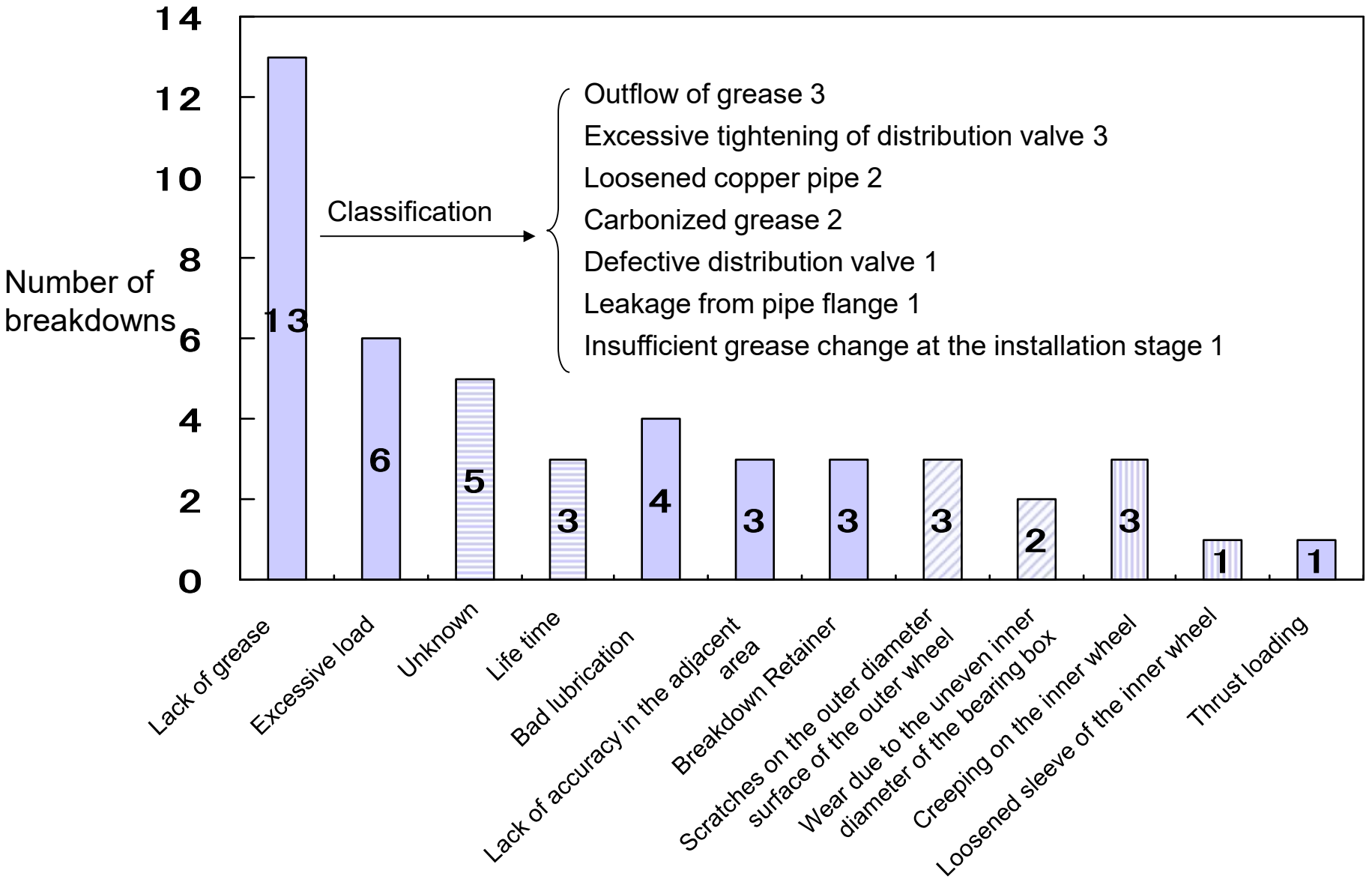
Cause classification of breakdowns of long hours in process industries



Element classification of breakdowns of long hours in process industries



Cause classification of bearing breakdowns



Organization

2.6.1. Four types of maintenance
2.6.2 The five zero-breakdown measures
2.6.3 AA, A, B and C machine classification
(1) Classification of equipment from the viewpoints of P, Q, C, D, S&M
(2) How to evaluate equipment (Example)
(3) General guideline of AA, A, B and C classification
2.6.4 Another kind of AA, A, B and C machine classification
2.6.5 Choosing a maintenance method
2.6.6 Organization for breakdown analysis
2.6.7 Daily breakdown meeting
2.6.8 Breakdown map
2.6.9 Daily breakdown control
2.6.10 Machine's sponsorship program
2.6.11 Breakdown repair overall flow
2.6.12 Breakdown repair direct going rate (example)

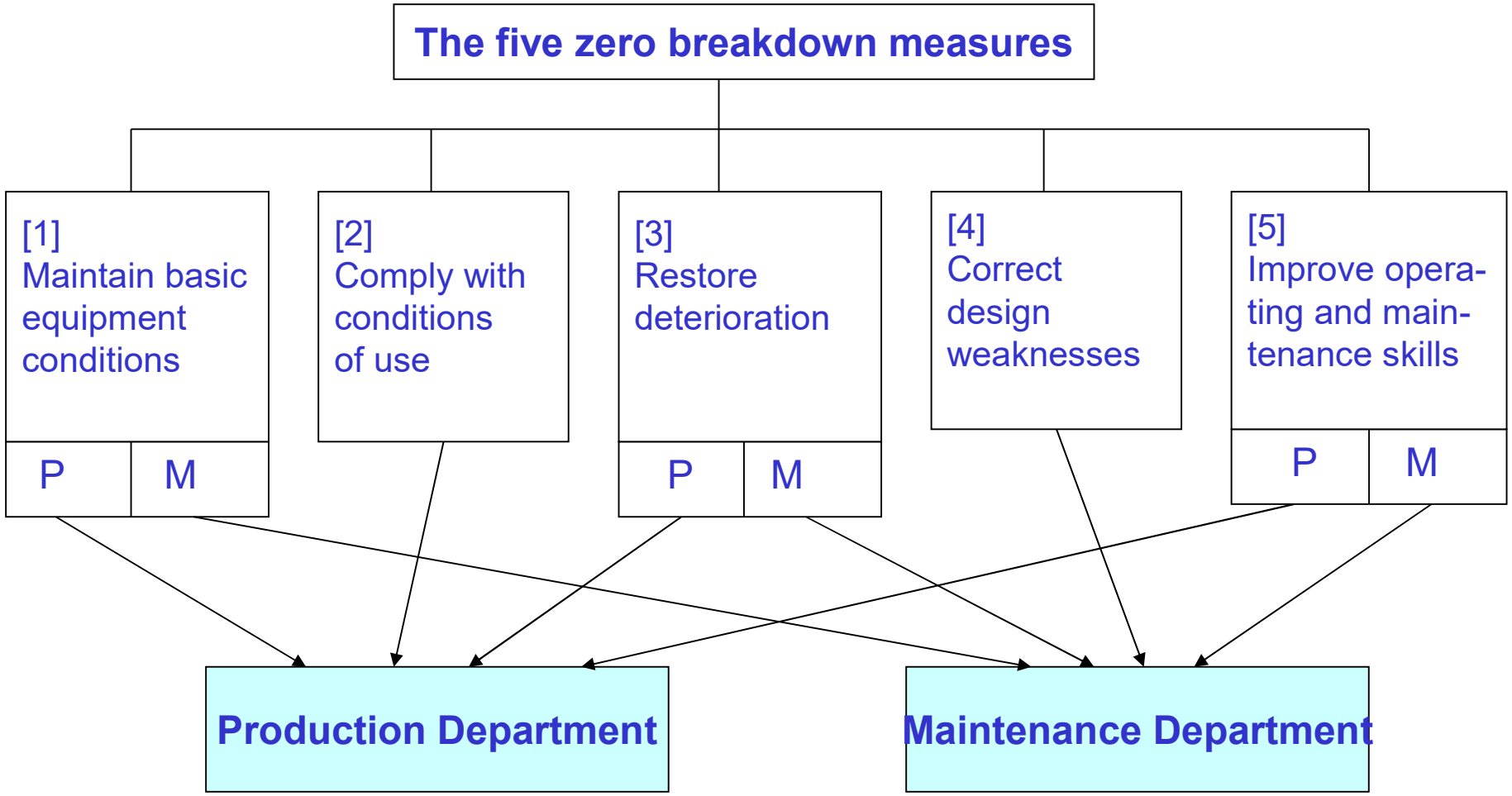
Four types of maintenance organization

(1) Decentralized Maintenance	(2) Centralized Maintenance		
(1) Maintenance by line people	((2) Maintenance by maintenance Dept. --Facility design and maintenance are taken care of by the same maintenance personnel.	(3) Maintenance by maintenance Dept. --Separate activity between facility design and maintenance	(4) Maintenance by maintenance Dept. --(3) + assignment of maintenance to operators
Example *Manufacturing Dept. - Manufacturing Sec. - Maintenance Sec. *Engineering Dept. (Facility design)	Example *Manufacturing Dept. - Manufacturing Sec. *Engineering Dept. - Engineering Sec. in charge of facility design and maintenance	Example *Manufacturing Dept. - Manufacturing Sec. *Engineering Dept. - Facility Design Sec. - Maintenance Sec.	Example *Manufacturing Dept. - Manufacturing Sec. Operation Maintenance *Engineering Dept. - Facility Design Sec. - Maintenance Sec.

Maintenance activities

Merits	(1)	(2)	(3)	(4)
* Prompt countermeasures against facility troubles	○	○	○	○
* Promotion of planned maintenance activities/Easier recognition of the weak points of facilities	○		○	○
* Close link with the workshop	○			○
* Feedbacking of maintenance information into design				○
Demerits				
* Work unbalance between design and maintenance departments/Problems of facilities are not clearly recognized		○		
* Difficulty in carrying out well planned maintenance activities on the floor closely linked with lines		○	○	○
* Difficulty in carrying out maintenance prevention together with the design department	○			
* Difficulty in improving specialized maintenance techniques from the long-term point of view	○			

The five zero-breakdown measures



The five zero-breakdown measures

[1] Maintain basic equipment conditions

P : Establish basic conditions

1. Cleaning

   Eliminate causes of accelerated deterioration.

2. Tightening

   Check nuts and bolts and prevent loosening.

3. Lubrication

- Lubricate where needed and replace dirty lubricants.
- Improve lubrication systems.
- Standardize lubricant types.

4. Prepare cleaning, checking and lubricating standards.

The five zero-breakdown measures

[1] Maintain basic equipment conditions

M : Abolish environments causing accelerated deterioration

1. Countermeasures for major contamination sources

- Expose contamination sources.
- Perform general inspection of powder scatter locations.
- Perform general inspection of powder collection and disposal equipment.
- Reduce sources of powder spills, liquid leaks, and gas leaks.
- Remove accumulated materials from buildings and structures.

2. Countermeasures against important inaccessible places

- Identify hard-to-check and hard-to-measure points.
- Identify areas of poor layout.
- Improve inaccessible places.

3. Support autonomous maintenance improvements in contamination sources and inaccessible places

The five zero-breakdown measures

[2] Comply with conditions of use

1. Set operating and handling conditions

- Set values for pressure, degree of vacuum, temperature, concentration, viscosity, moisture content, grain size, etc.

2. Standardize operation and handling methods

- Prepare manuals and provide OJT.

3. Standardize adjustment/setting tasks

- List adjustment points
- Improve adjustment methods

4. Standardize process startup and shutdown procedures.

The five zero-breakdown measures

[3] Restore deterioration

P : Detect and predict deterioration

1. Check processes using the five senses and identify areas of deterioration.
2. Check equipment using the five senses and identify deteriorated parts.
3. Prepare periodic patrol checking standards.
4. Prepare periodic inspection and replacement standards.
5. Set and standardize replacement and restoration times :

   e.g. :

- Filter washing times.
- Cycle times for catalysts, etc.
- Sieve screen cleaning times.

6. Devise techniques for recognizing signs of process abnormality.
7. Formulate condition monitoring standards

- Specify measurements and improve measuring equipment.

The five zero-breakdown measures

[3] Restore deterioration

M : Restore and prevent deterioration

1. Evaluate and prioritize equipment (select PM equipment).
2. Prepare equipment ledgers

- Control equipment records.
- Optimize service intervals.

3. Standardize periodic overhaul inspection procedures

- Prepare annual maintenance calendar.
- Computerize information processing.

4. Standardize disassembly, assembly and replacement tasks
5. Improve work methods for inspection, replacement and repair.
6. Tighten control of maintenance materials and spares

- Standardize and centralize.
- Draw up inventory control standards.

7. Tighten control of drawings and data

- Share and centralize data.
- Improve retrieval techniques.

The five zero-breakdown measures

[4] Correct design weaknesses

1. Eliminate weaknesses inherent in equipment as a result of design or fabrication defects

- Dimensions, strength.
- Materials.
- Equipment construction, parts construction.
- Shape (chute gradients, etc.).
- Corrosion resistance.
- Wear resistance.

2. Improve resistance to environmental conditions

- Improve anti-corrosion painting..
- Investigate new corrosion-resistant materials.
- Consider new lining materials.

3. Improve bottleneck processes

- Introduce measures to prevent overloading.

4. Adopt measures to prevent recurrence of major failures

The five zero-breakdown measures

[5] Improve operating and maintenance skills

P : Ensure correct operation and manipulation

1. Prevent operating and handling errors

- Prepare manuals detailing changes in physical properties and operating conditions.
- Display correct adjustment values on equipment.
- Introduce more visual controls.
- Mark pipes with flow direction and contents.
- Indicate whether valves are open or shut.
- Provide clear displays on measuring instruments.
- Indicate rotation directions.
- Employ error-proofing and tagging.

2. Prevent errors in dealing with abnormalities

- Standardize procedures for handling abnormalities.
- Standardize prediction techniques.

3. Ensure safe working

- Install safety interlocks.
- Indicate whether switches are on or off.
- Provide accident prevention training and sharpen individual danger awareness.

The five zero-breakdown measures

[5] Improve operating and maintenance skills

M : Ensure error-free repairs

1. Prevent repair errors

- Analyze recurrent failures.
- Improve repair methods.
- Standardize materials selection.
- Standardize parts and spares.
- Formulate work standards.
- Draw up work order standards.

2. Prevent acceptance errors

- Strengthen supervisory skills.
- Formulate acceptance standards.
- Establish an operation and maintenance acceptance system.

3. Prevent test-operation errors

- Standardize test operation procedures.
- Prepare checklists.

The five zero-breakdown measures

Production Department

1. Daily checking and lubricating
2. Operation and manipulation
3. Early detection of abnormalities
4. Adjustment and setting
5. Minor improvements to contamination sources and inaccessible places

Maintenance Department

1. Periodic checking and inspection/periodic servicing
2. Improvement of major contamination sources and inaccessible places
3. Equipment improvement
4. Recurrence prevention and breakdown analysis
5. Test operation and acceptance of new equipment

(1) Classification of equipment from the viewpoints of P, Q, C, D, S & M

Criteria	Evaluation
P	・No spare equipment. ・Machines with many breakdowns. ・Production loss is big when the machine breaks down. ・Equipment with big output variation.
Q	・Equipment which influences quality much. ・Equipment with big quality variation. ・Equipment which influences quality when a breakdown occurs.
C	・Equipment which processes expensive raw material. ・Labor intensive equipment. ・Equipment which consumes much power and/or heat. ・Equipment which produces big losses when a breakdown takes place.
D	・Equipment which processes many different parts. ・Equipment placed at a later stage of a line. ・Equipment whose production timings are important. ・Equipment which will delay overall production if a breakdown takes place.
S and M	・Equipment requiring safety. ・Ventilation equipment. ・Pollution related equipment. ・Equipment which will damage environment when it breaks down.

(2) How to evaluate equipment (Example)

		Point
P	The entire plant will stop if the equipment breaks down.	5
	Part of production will be lost if it breaks down.	3
	No influence to production even if it breaks down.	0
Q	The equipment will influence quality a great deal if it breaks down.	5
	The equipment will influence quality if it breaks down.	3
	The equipment will not influence quality even if it breaks down.	0

(-Continued)

Maintenance	Sporadic breakdowns will cost a huge repair money.	5
	Breakdowns will cost a certain amount of money.	3
	No substantial repair cost.	0
S	Possesses risk of fire and scattering poison.	5
	Equipment breakdown may bring out a disaster.	3
	No substantial risk.	0
Machine age	More than 20 years Between 10 and 20 years Less than 10 years.	5 3 0

(3) General guidance of AA, A, B and C machine classification

	Very important equipment	Important equipment	Important after A class	Low priority equipment
The degree of importance	AA	A	B	C
%	5 ～ 7%	7, 8 ～ 20%	35%	40%
Classification	PM special Class	PM 1st Class	PM 2nd Class	BM Class

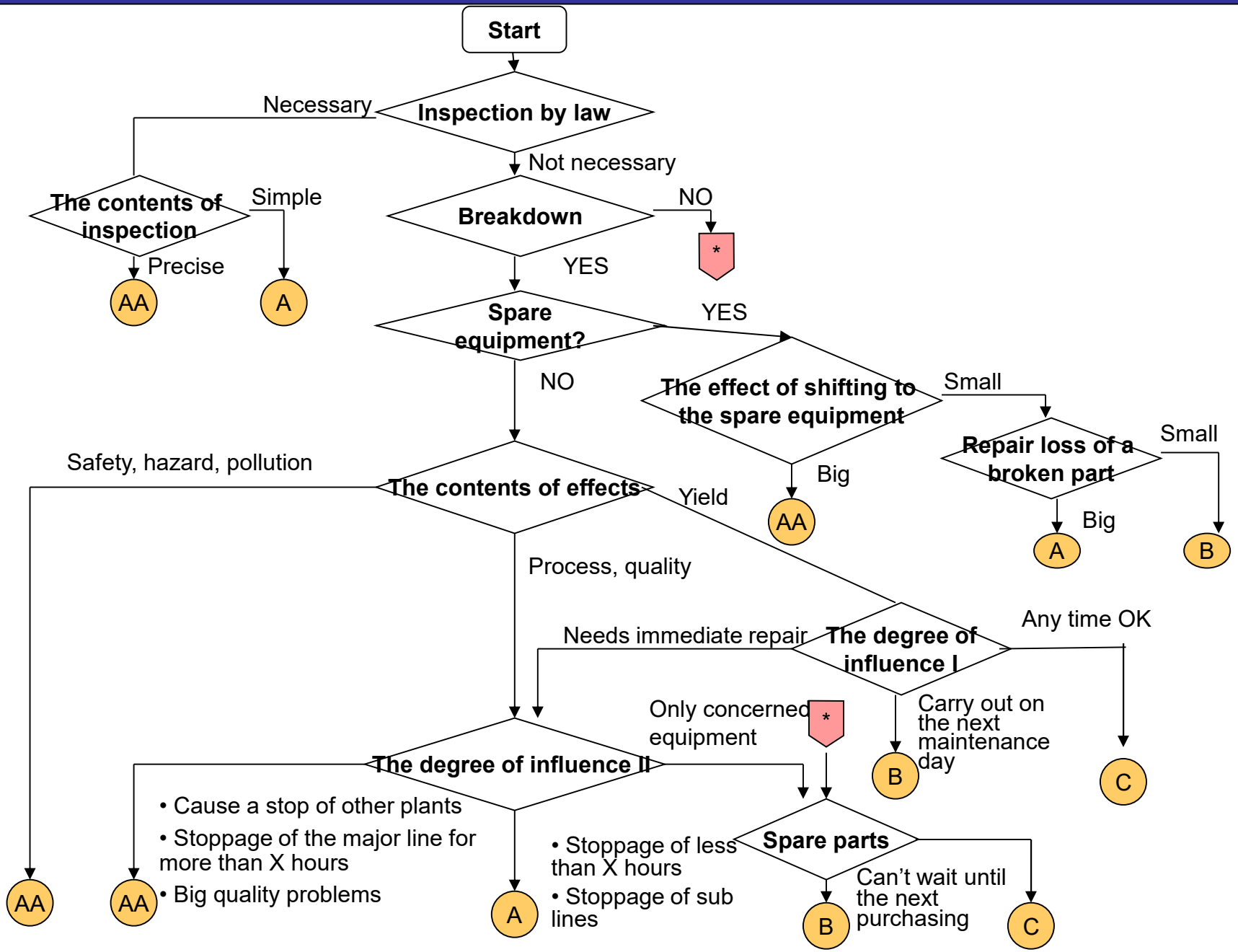
AA : Sophisticated CBM (Continuously monitored) + TBM

A : Normal CBM (Periodic diagnosis) + TBM

B : TBM + BM

C : Mainly BM

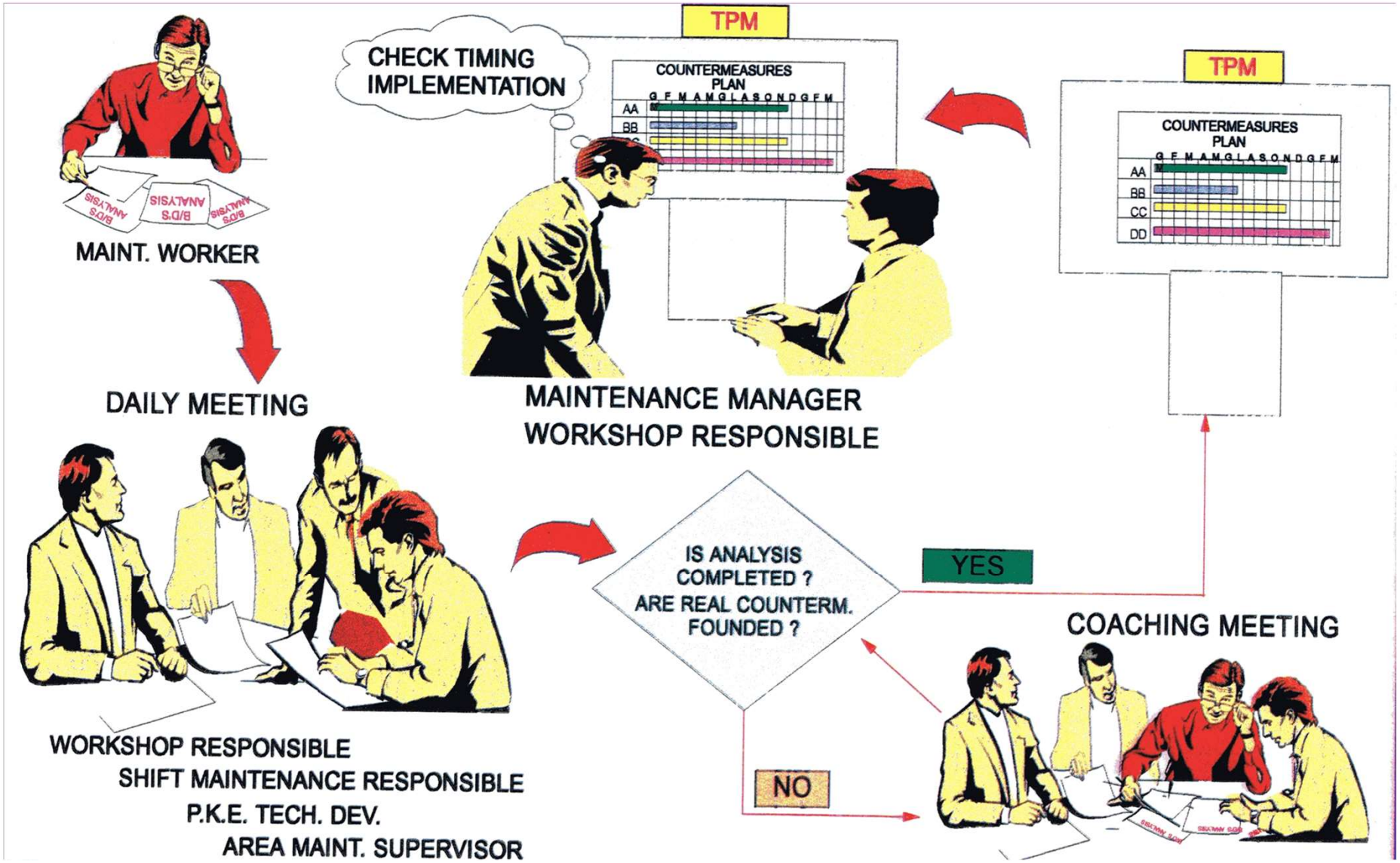
Another kind of AA, A, B and C machine classification



Choosing a maintenance method

Maintenance method		AA	A	B	C
Rank		Preventive maintenance		BM	
Maintenance schedule		○	○		
Inspection	Precise	○			
	Simple	○	○		
Spare parts		○	○	○	
Lubrication		○	○	○	○

Organization for breakdown analysis



Daily breakdown meetings

Objectives:

- ✓ Standardize the criteria to classify the types of breakdowns for all machines;
- ✓ Standardize the criteria to classify the breakdown analysis;
- ✓ Horizontal extension inside the shop floor itself
- ✓ Correct the lack of know-how
- ✓ Shop floor integration

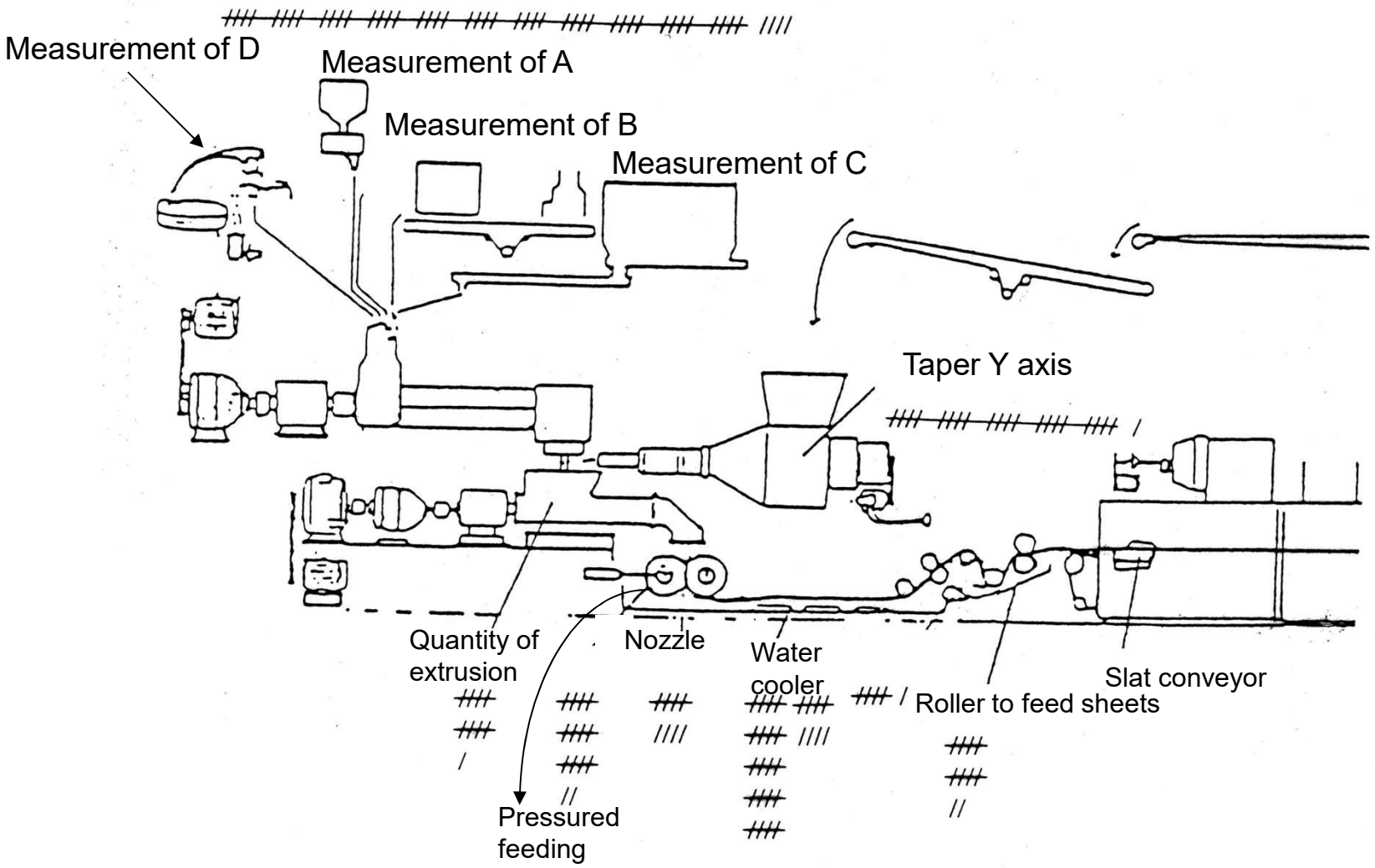
Participants:

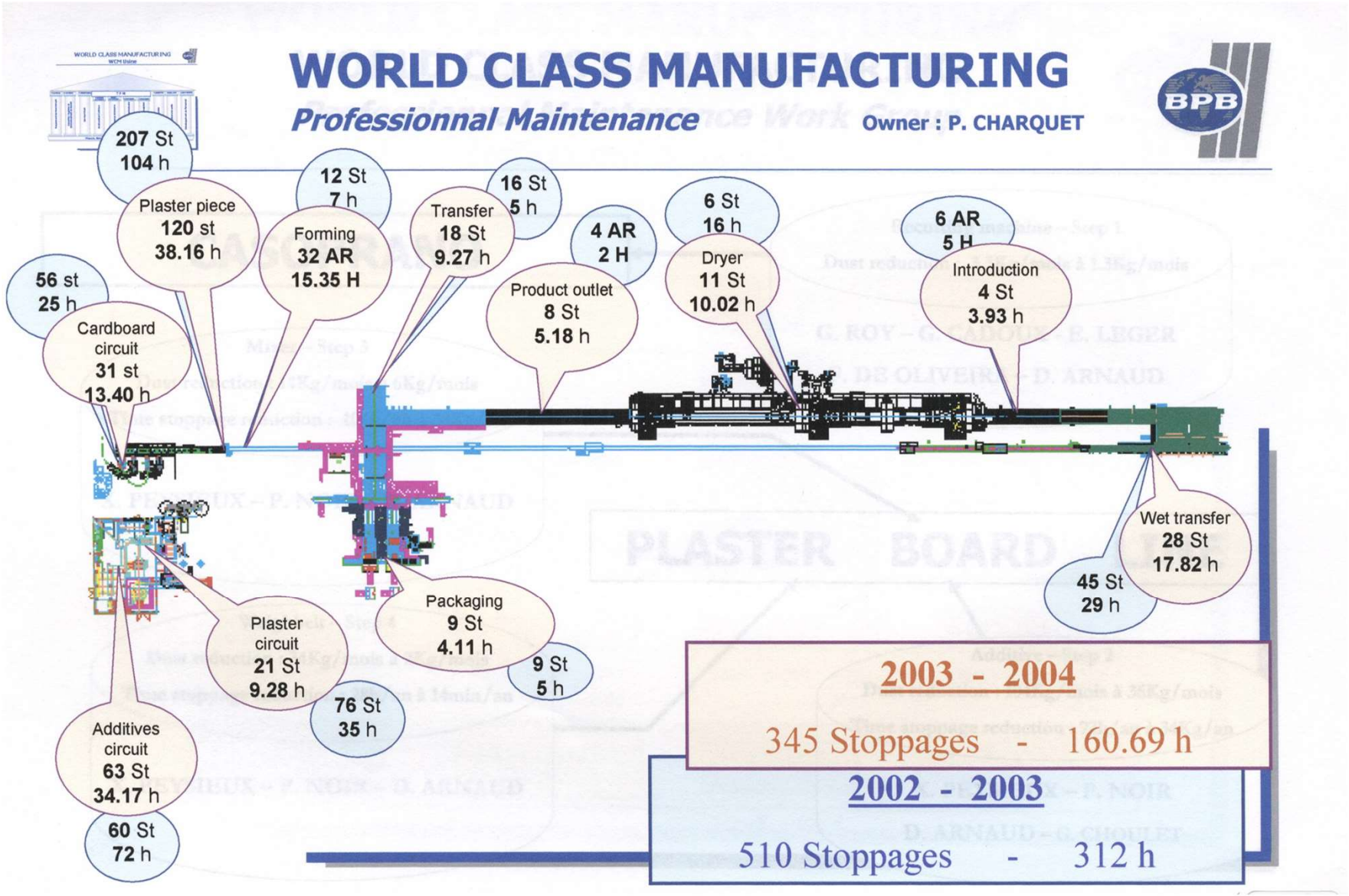
- ✓ Section head
- ✓ Corr. Maint. Supervisor
- ✓ Prev. Maint. Supervisor
- ✓ Reliability Eng.

Frequency:

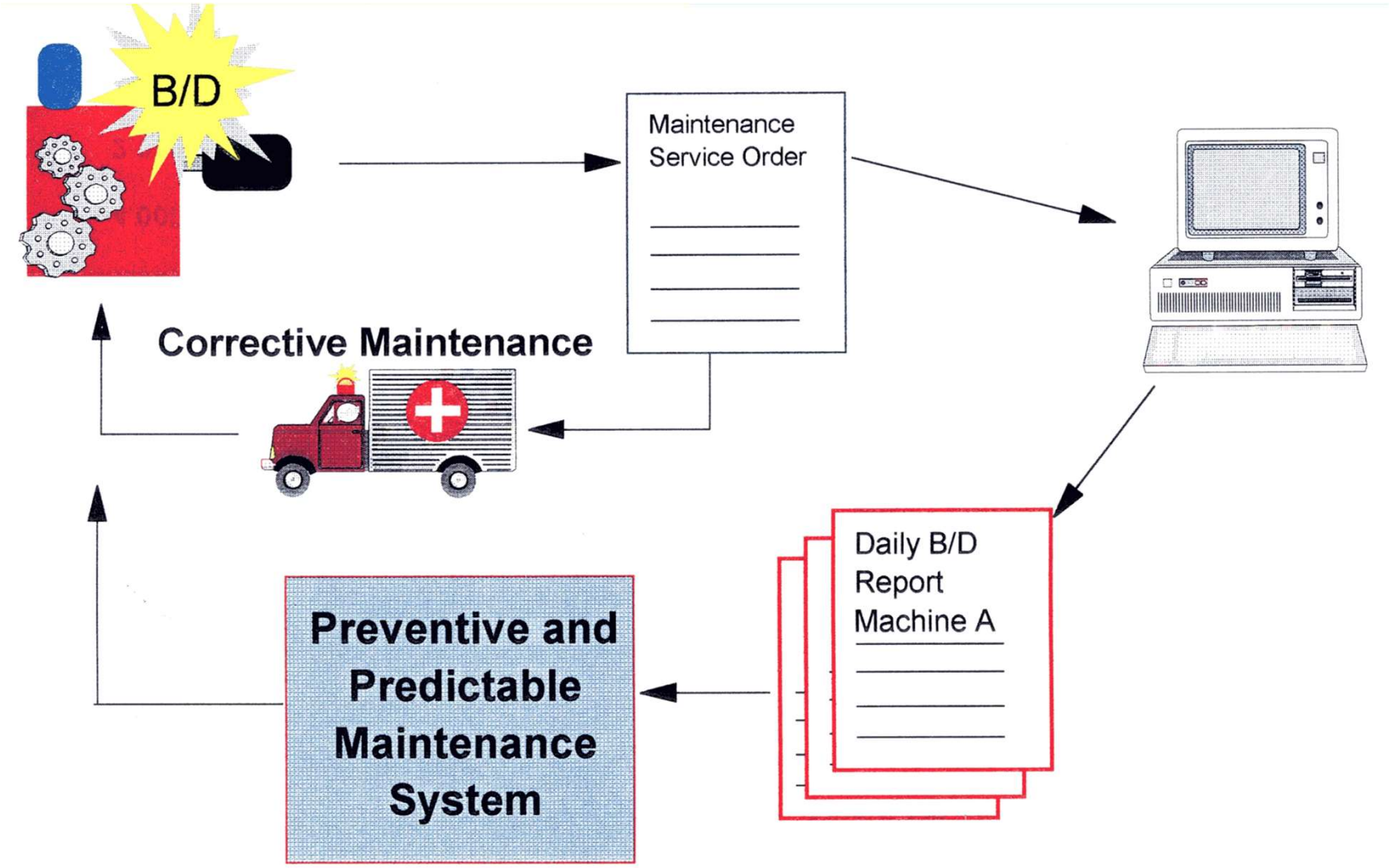
Every day

Breakdown map




WORLD CLASS MANUFACTURING
Professionnal Maintenance
Owner : P. CHARQUET
BPB
207 St
104 h
Plaster piece
120 st
38.16 h
12 St
7 h
Forming
32 AR
15.35 H
16 St
5 h
Transfer
18 St
9.27 h
4 AR
2 H
Product outlet
8 St
5.18 h
6 St
16 h
Dryer
11 St
10.02 h
6 AR
5 H
Introduction
4 St
3.93 h
56 st
25 h
Cardboard
circuit
31 st
13.40 h
Wet transfer
28 St
17.82 h
45 St
29 h
Packaging
9 St
4.11 h
9 St
5 h
Plaster
circuit
21 St
9.28 h
76 St
35 h
Additives
circuit
63 St
34.17 h
60 St
72 h
2003 - 2004
345 Stoppages - 160.69 h
2002 - 2003
510 Stoppages - 312 h

Daily breakdown control



Machine's sponsorship program

Objectives:

- Know-how increase
- Failure prevention
- Greater individual involvement
- More people involved
- Delegation of responsibilities
- Motivation and enthusiasm

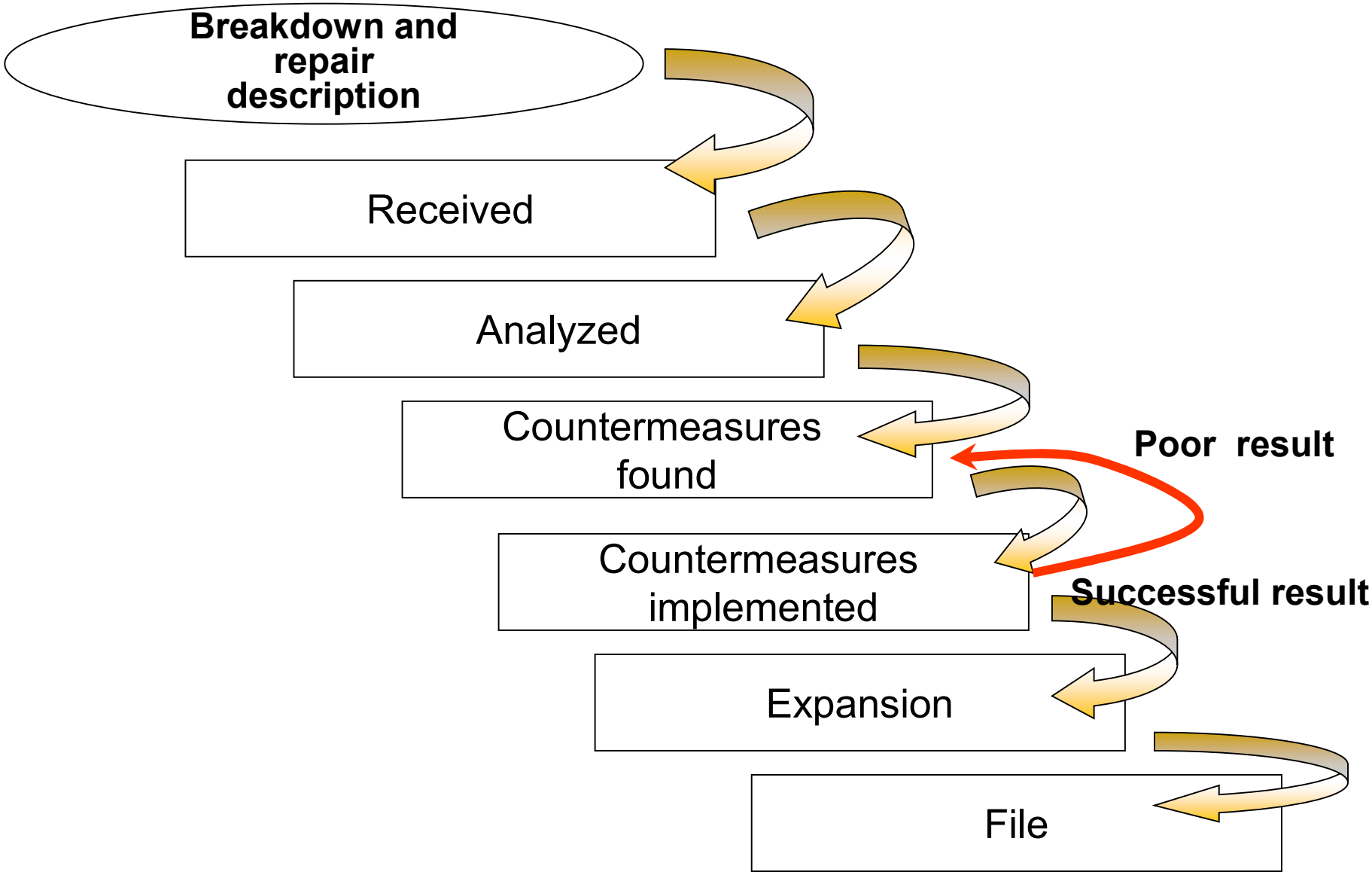
Through:

- Team work
- Check list
- Autonomous maintenance
- Breakdown analysis
- Follow-up

FISCHER 1/2	AKIRA (ET) CELSO (MEC)
TRGA-1	
TRG	
TRGA-2	BRENO (ET) VALDEMIR (MEC)
TRGA-3	
TRGA-4	

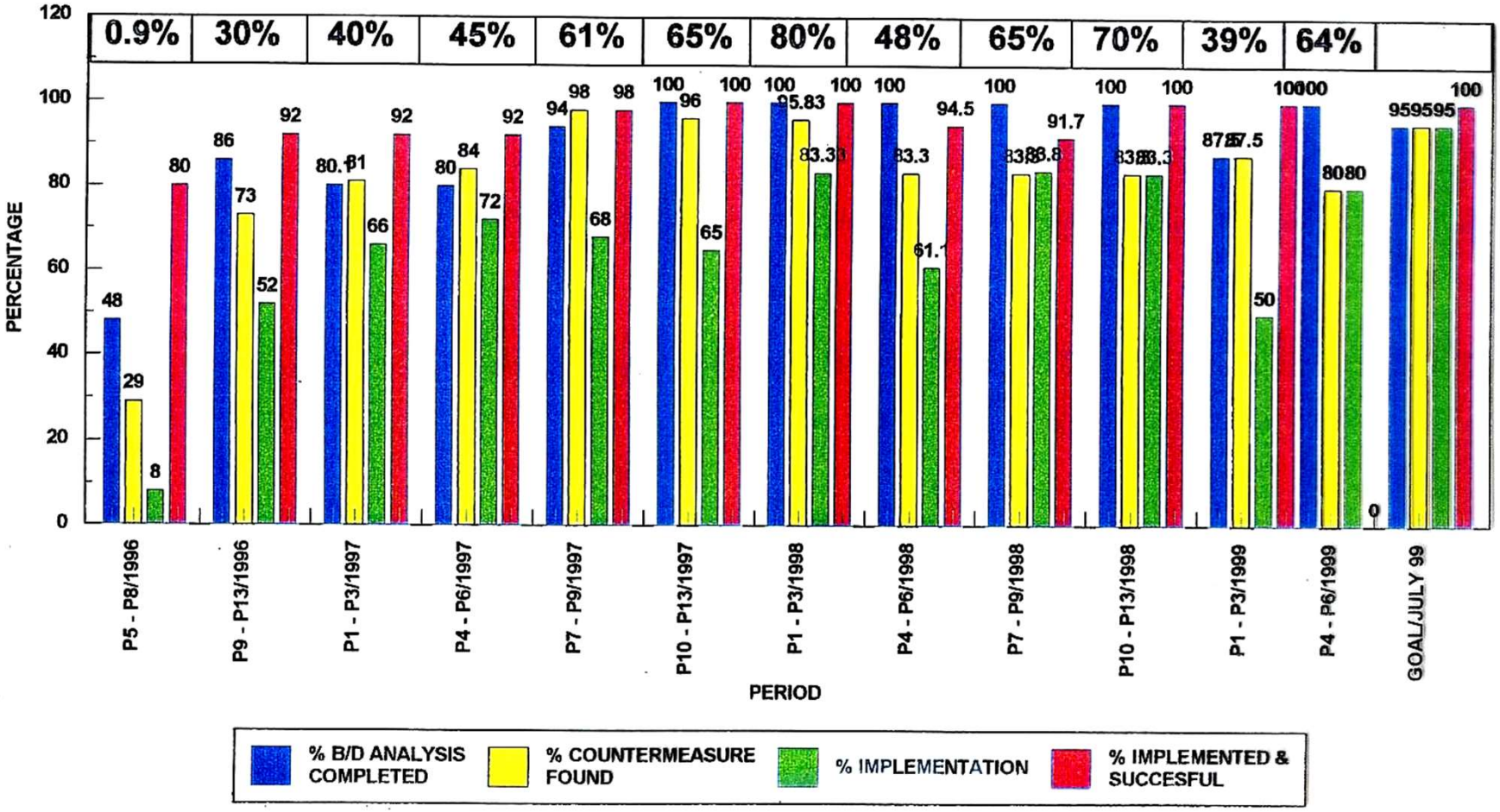
CTB 1/2	
TTM-1/2	MARCELO (EL) HILDO (MEC)
TTM-3/4	
RM30-3	MARCOS LEME (ET) VALDIR CUSTÓDIO (MEC)
RM30-2	VALDIR (ET) DONIZETE (MEC)
RM30-1	ERNANE (ET) ADELQUE (MEC)
RM-3	EPAMINONDAS (ET) LUIS CARDOSO (MEC)

Breakdown repair overall flow



Breakdown repair direct going rate (example)

Activity: Eliminate failures by improving maintenance, analyzing failures and eliminating root causes, and implementing countermeasures.



3. Step by Step Approach to Establish a Planned Maintenance System

- 3.1 Route Map to Zero Breakdown
- 3.2 From Phase 1 to Phase 4
- 3.3 BM
- 3.4 TBM
- 3.5 CBM
- 3.6 Stabilize MTBF
- 3.7 Lengthen Equipment Life Span
- 3.8 Periodically Restore Deterioration
- 3.9 Predict Breakdowns
- 3.10 Concept of Zero Equipment Breakdown
- 3.11 Zero Breakdowns in Four Phases
- 3.12 Damages and Countermeasures
- 3.13 Common Failure Modes and Their Causes
- 3.14 Four Faces to Zero Failure of Static Equipment (Example)
- 3.15 Seven Steps of Establishing a Planned Maintenance

3.15 Concept of Step-by-Step Activities

3.16 Planned Maintenance of Components

3.17 Planned Maintenance of Equipment

3.18 Importance of Making an Equipment Ledger

3.19 Examples of Planned Maintenance Goals

3.20 Necessary Accomplishments for Process Competent Operator

3.21 Support for AM

3.22 Check Situations

3.23 Harmful Effects of Inadequate Cleaning

3.24 Exposing Seven Types of Abnormalities

3.25 Model-Block-Area Deployment

3.26 Evaluation Maintenance Flow Diagram

3.27 Determination of Replacement Period

3.28 Flow Diagram for Preventing Recurrence of Unexpected Failure

3.29 Preventive Maintenance Task in TBM

3.30 Failure and Maintenance Information

3.31 Kinds of Maintenance Records and Purpose of Utilization

3.32 Planned Maintenance Master Plan

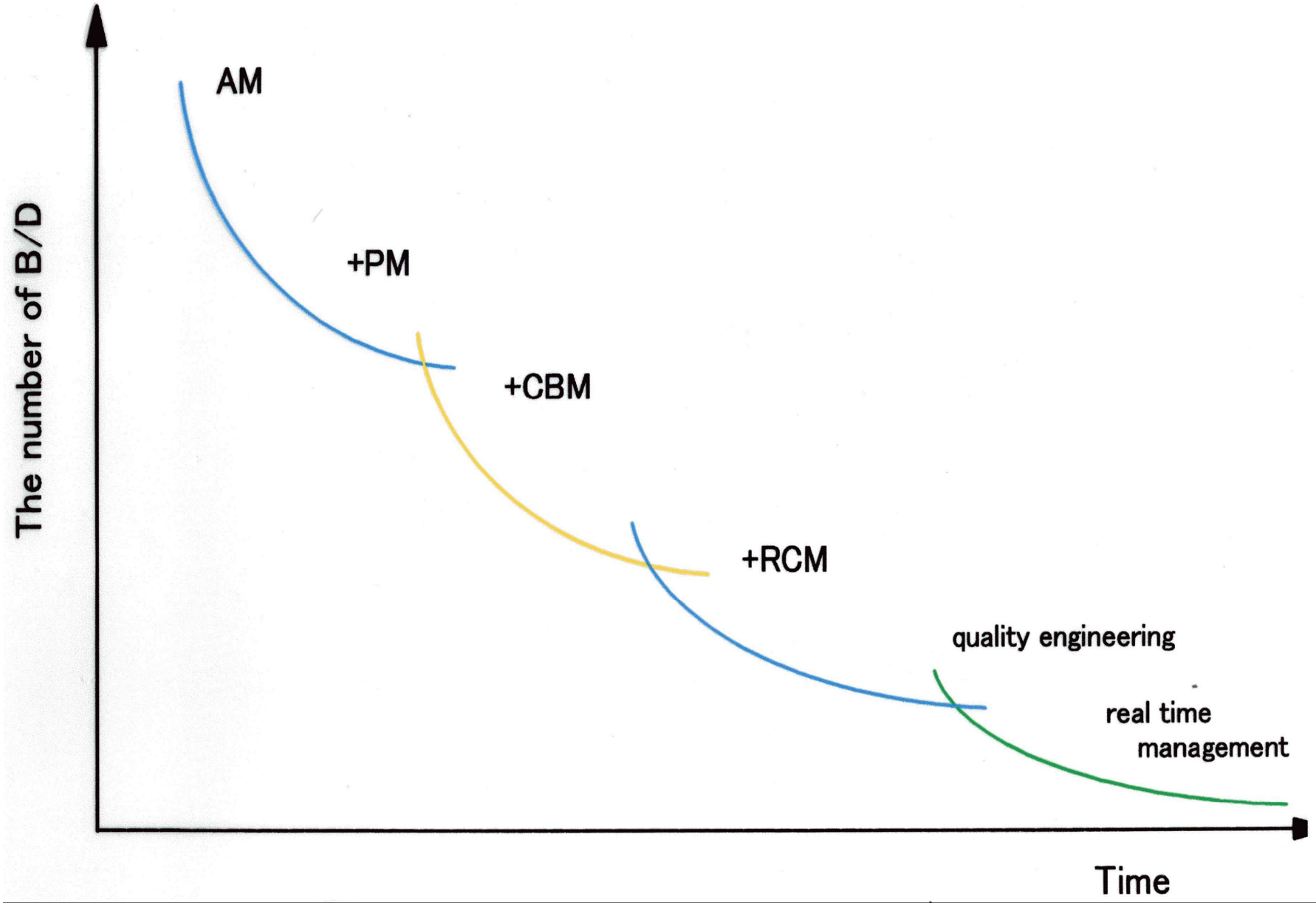
3.33 Integration of AM, PM and QM

3.34 Transition of Contents of Maintenance Work

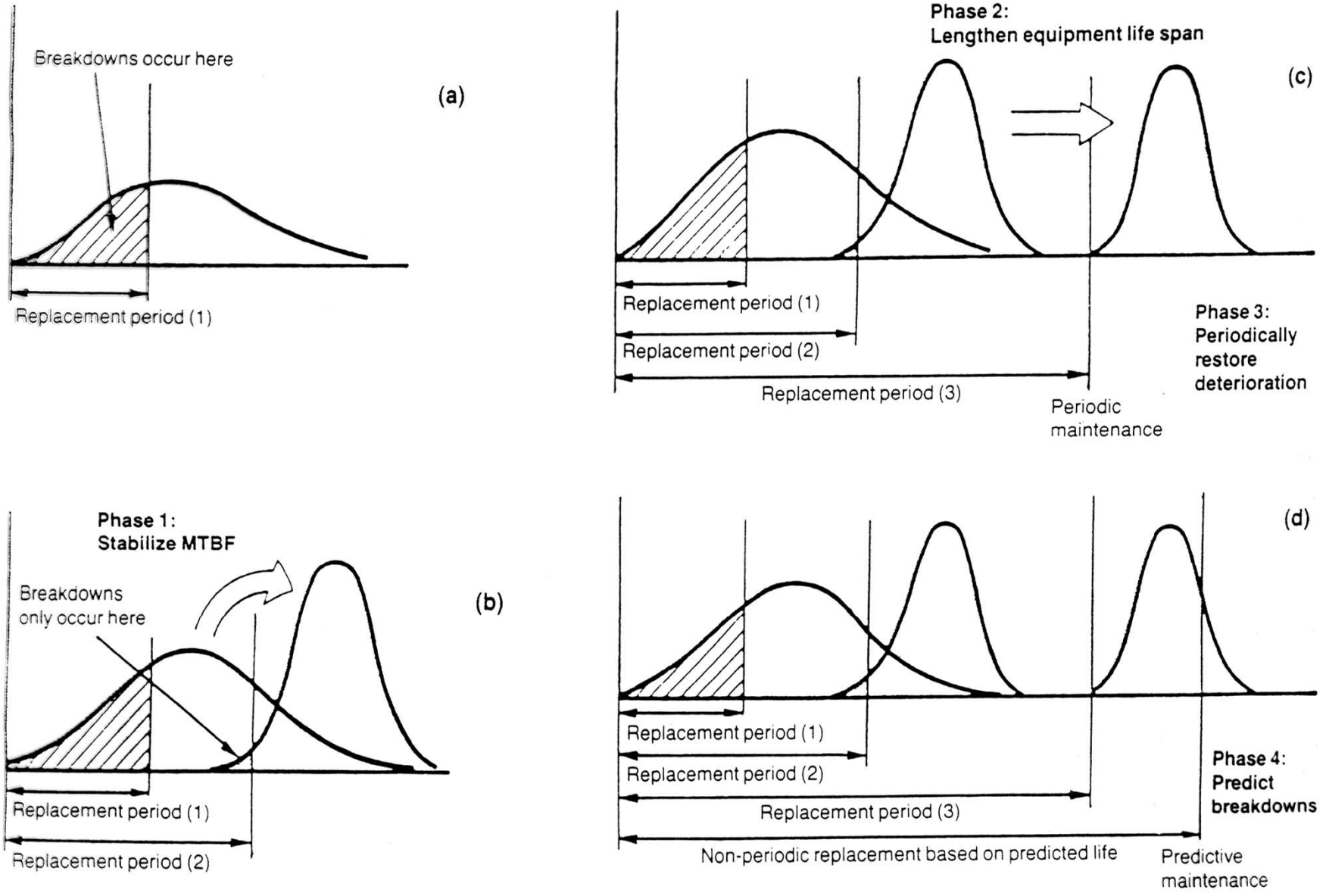
3.35 Change of Maintenance

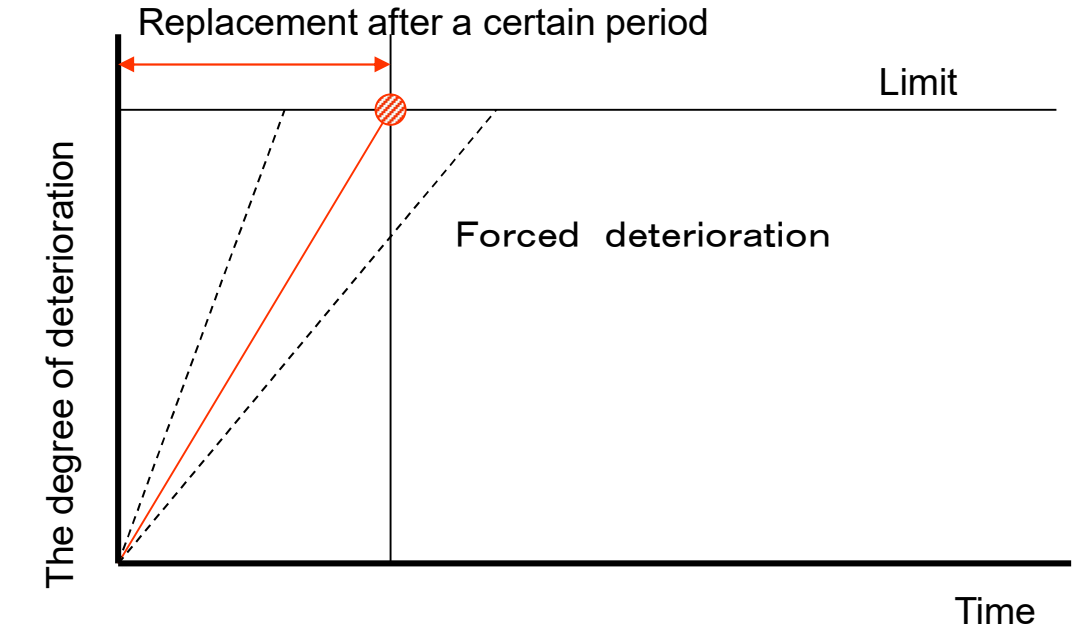
3.36 Planned Maintenance Check List

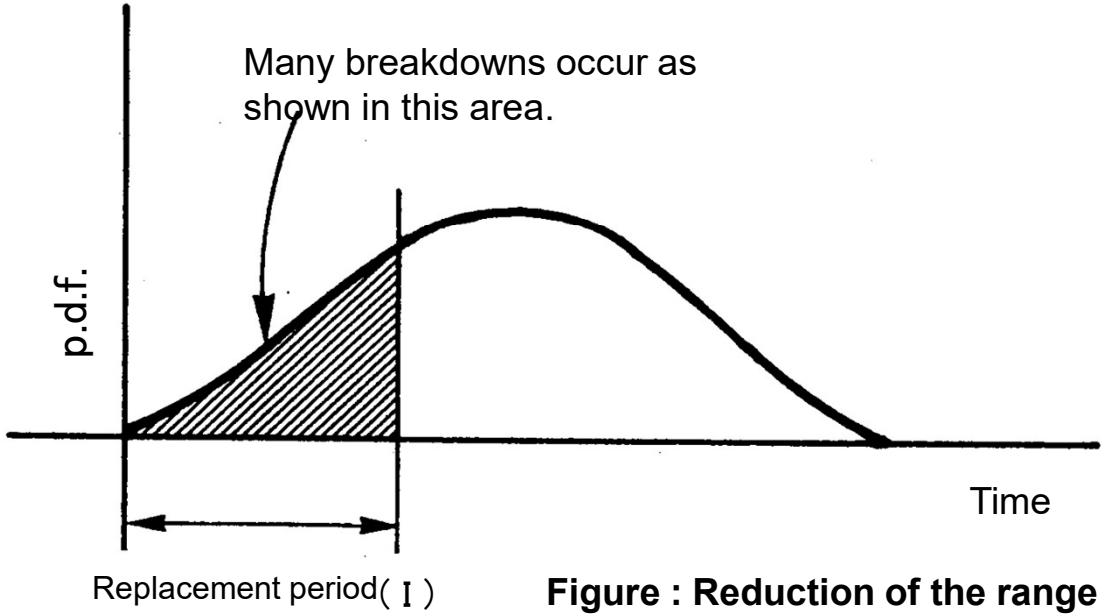
Route Map to Zero B/D



From Phase 1 to Phase 4





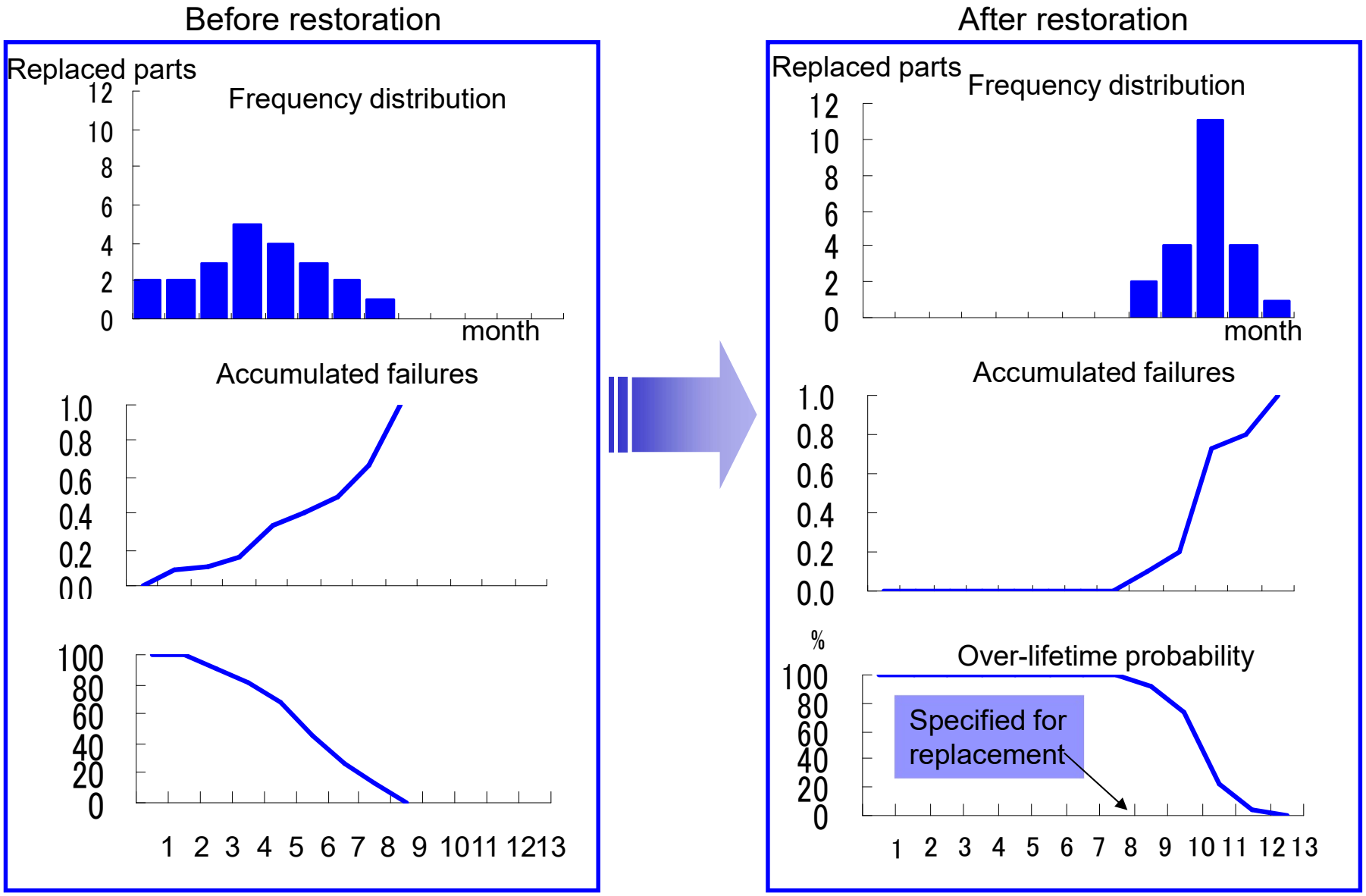


Figures show a short life span spread over a wide range characteristic of accelerated deterioration. If periodic maintenance is applied under these circumstances, maintenance cycles will be short and probably ineffective.

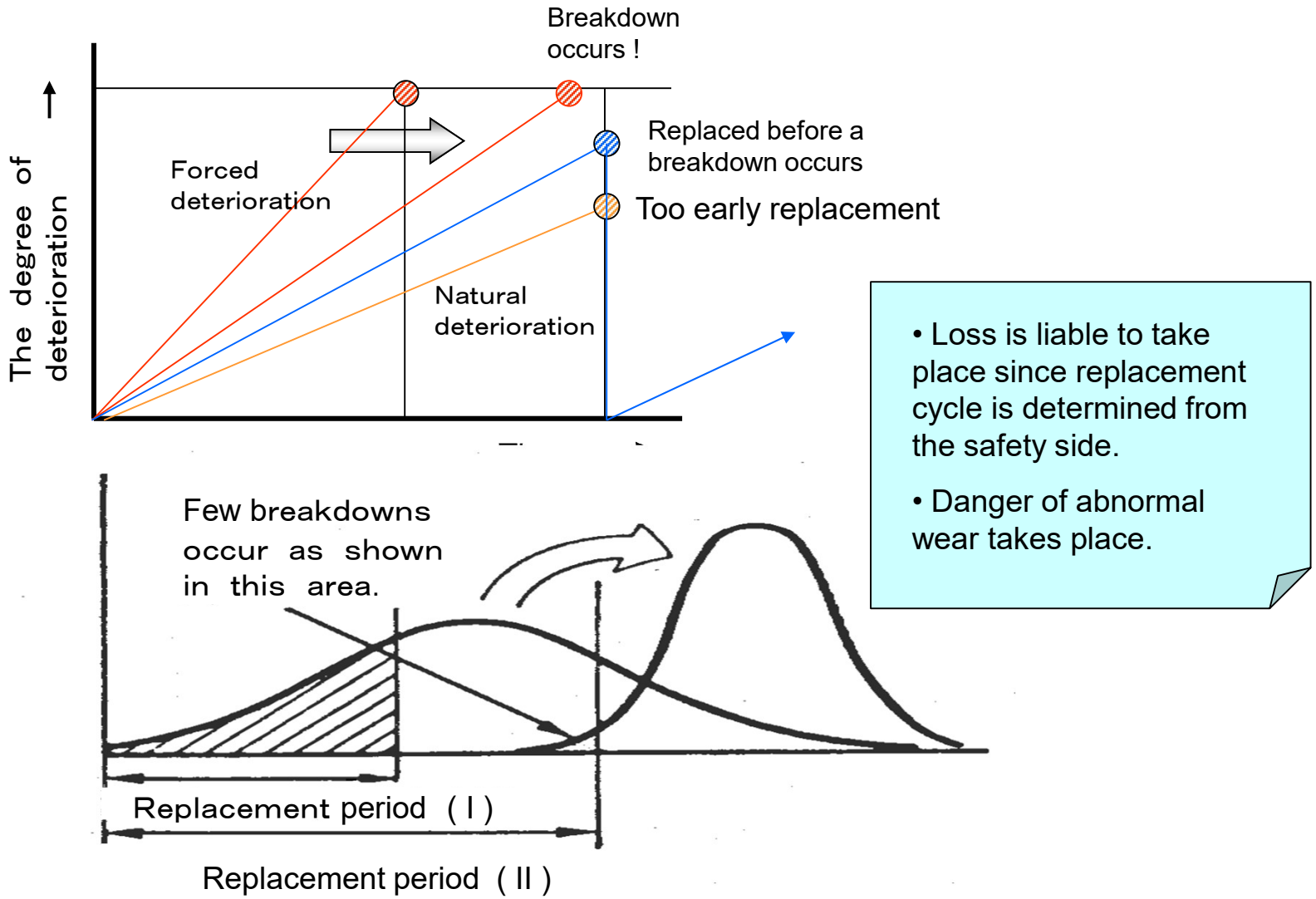
Figure : Reduction of the range of equipment lifespan by phase 1

Components Lifetime

22 analyzed machines

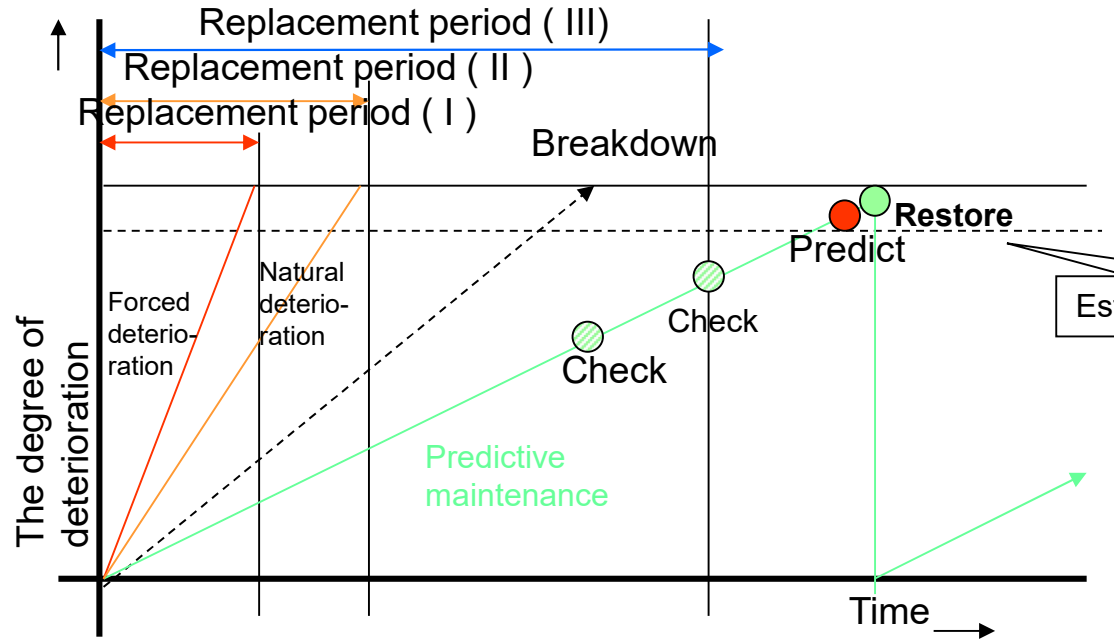


T B M



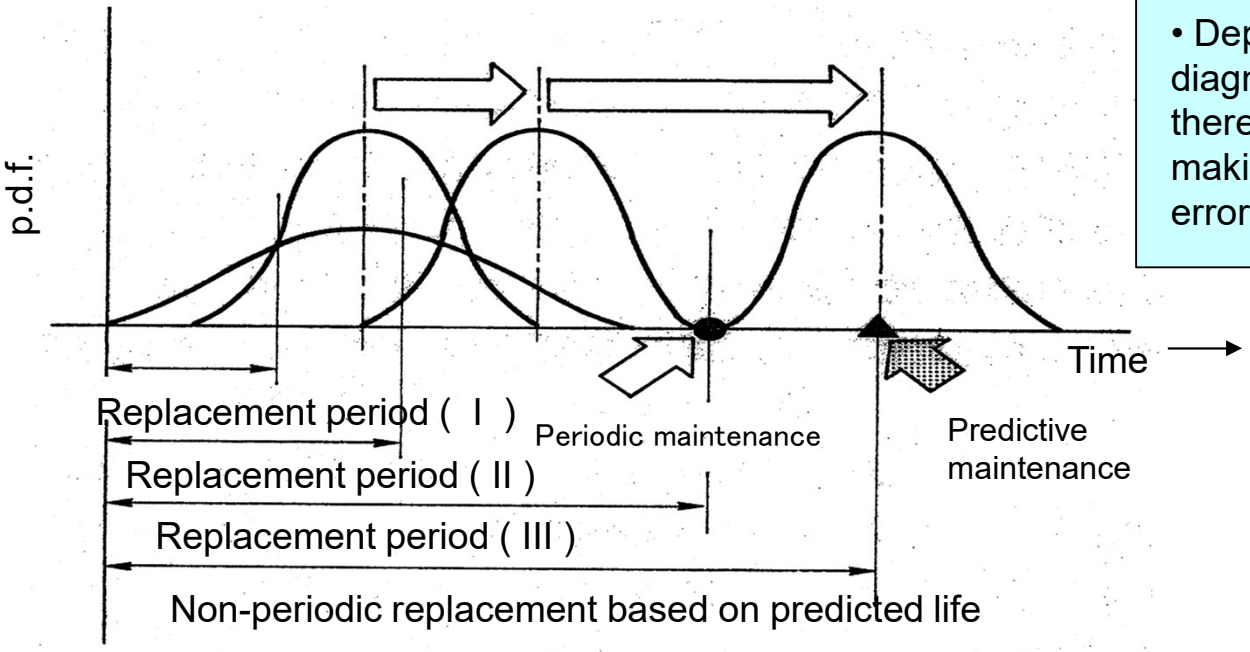
- Loss is liable to take place since replacement cycle is determined from the safety side.
- Danger of abnormal wear takes place.

C B M

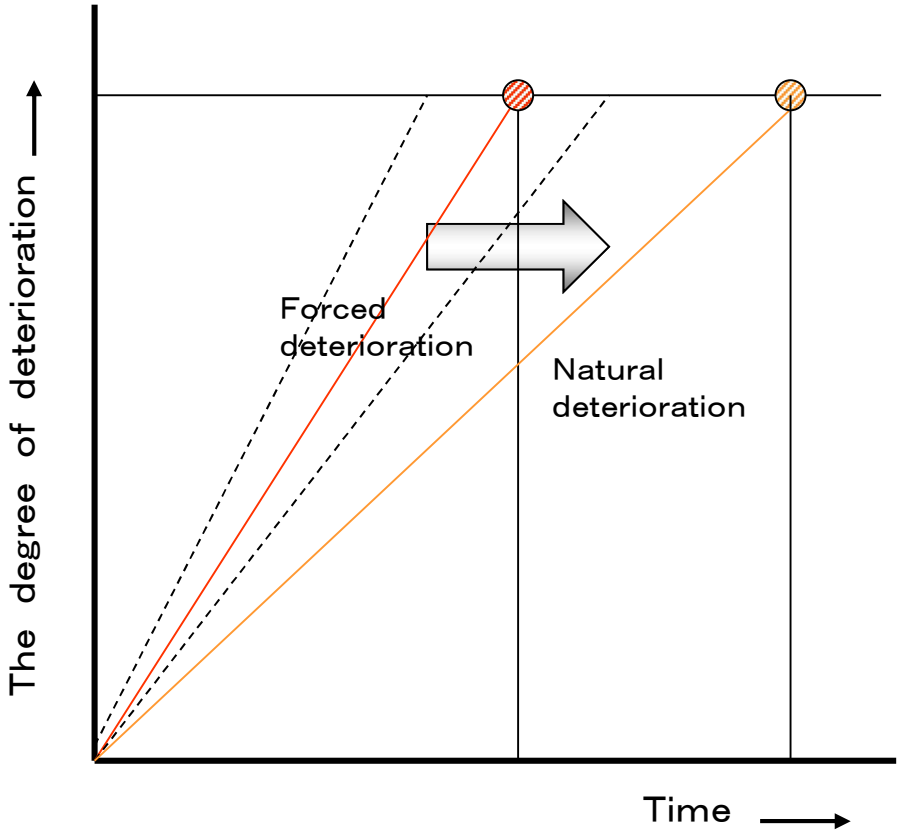


Established standard value

- Most economical because the part can be utilized up to almost the wear limit.
- Depending on the diagnosis technique, there is a risk of making a diagnosis error.



Phase 1 : Stabilize MTBF



Points :

- Detection of abnormalities by cleaning
- Countermeasures against the sources of dust and dirt
- Detection of minute defect and its improvement
- Maintaining of the basic conditions
- Clarification of the use condition and its observance

Phase 1 : Stabilize MTBF

Figure illustrates the effect of phase 1 :

When life spans are stabilized and lengthened through the elimination of accelerated deterioration, it lengthens maintenance cycles and reduces the likelihood of breakdowns.

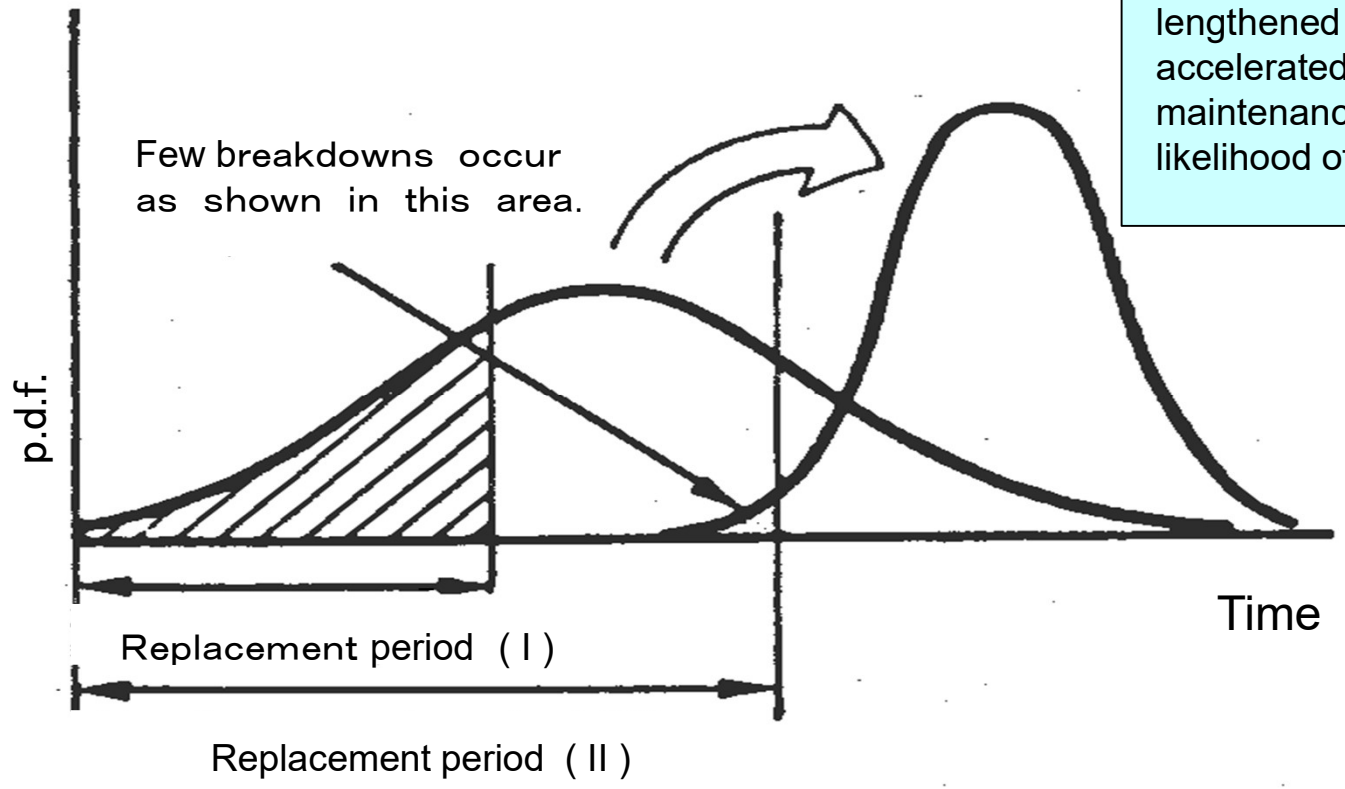


Figure : Lengthened equipment life span by phase 1

Hidden defects

Hidden defects are the ones which will eventually cause a failure but which have not yet taken place detected.
There are 3 types of hidden defects.

① Physically hidden defects: Defects which have not been attended due to the physical structures of the equipment

- Internal defects which go undetected by not being carried out overhaul.
- Defects which can not be detected because of the shape and / or position of the part (e.g. level gauge)
- Defect which cannot be detected by dust, dirt, etc (such as a crack in the Banbury mixer)

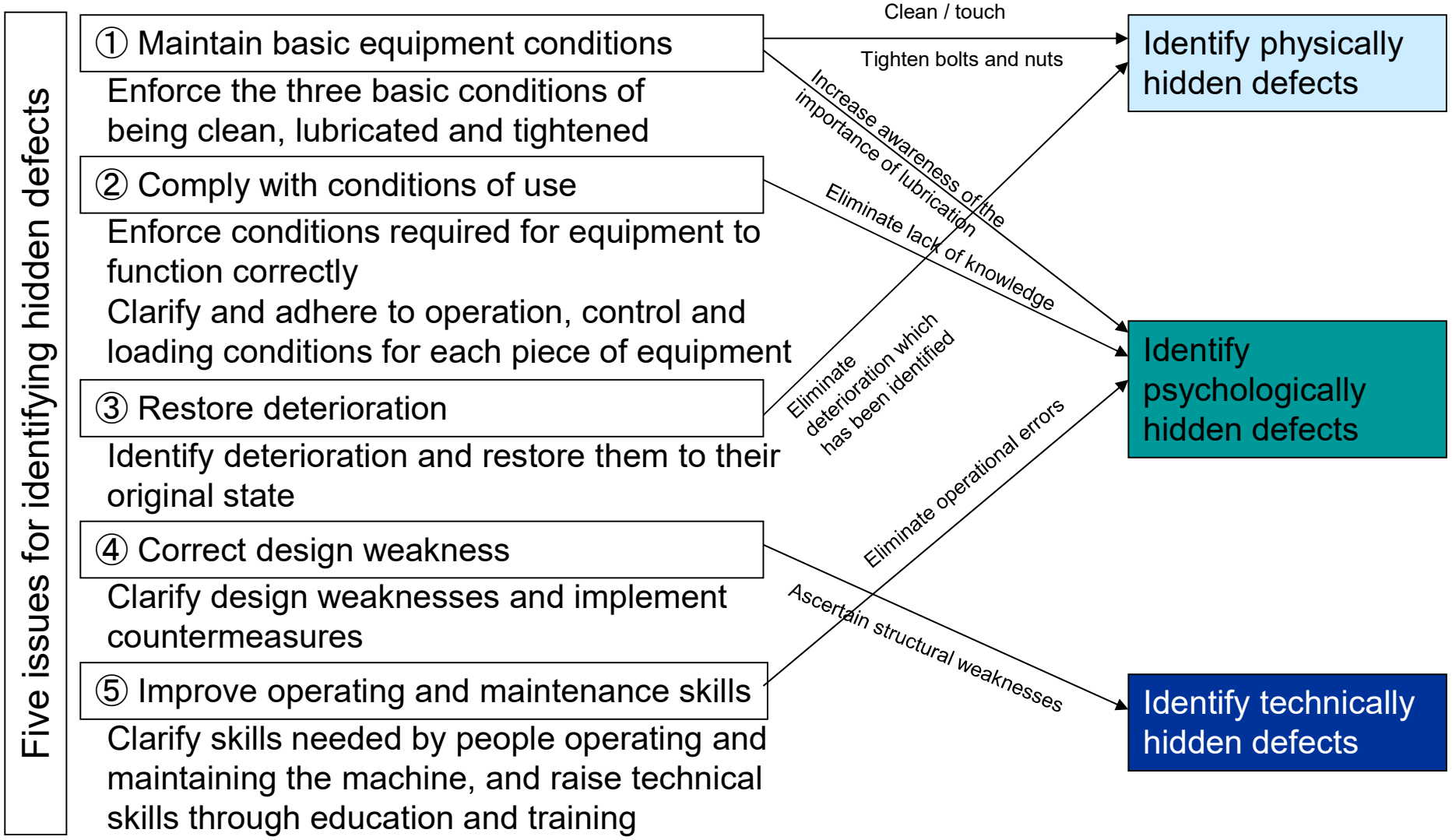
② Psychologically hidden defects: Defects which are overlooked due to the low level of awareness or skills among those in charge of the equipment

- Defects which are actually visible, but have been neglected
- Small defects which are ignored or not being dealt with because they are not considered as important (minor defects)
- Defects which are not noticed even though there are clear signs of abnormality. (Importance of distinction between normal and abnormal)

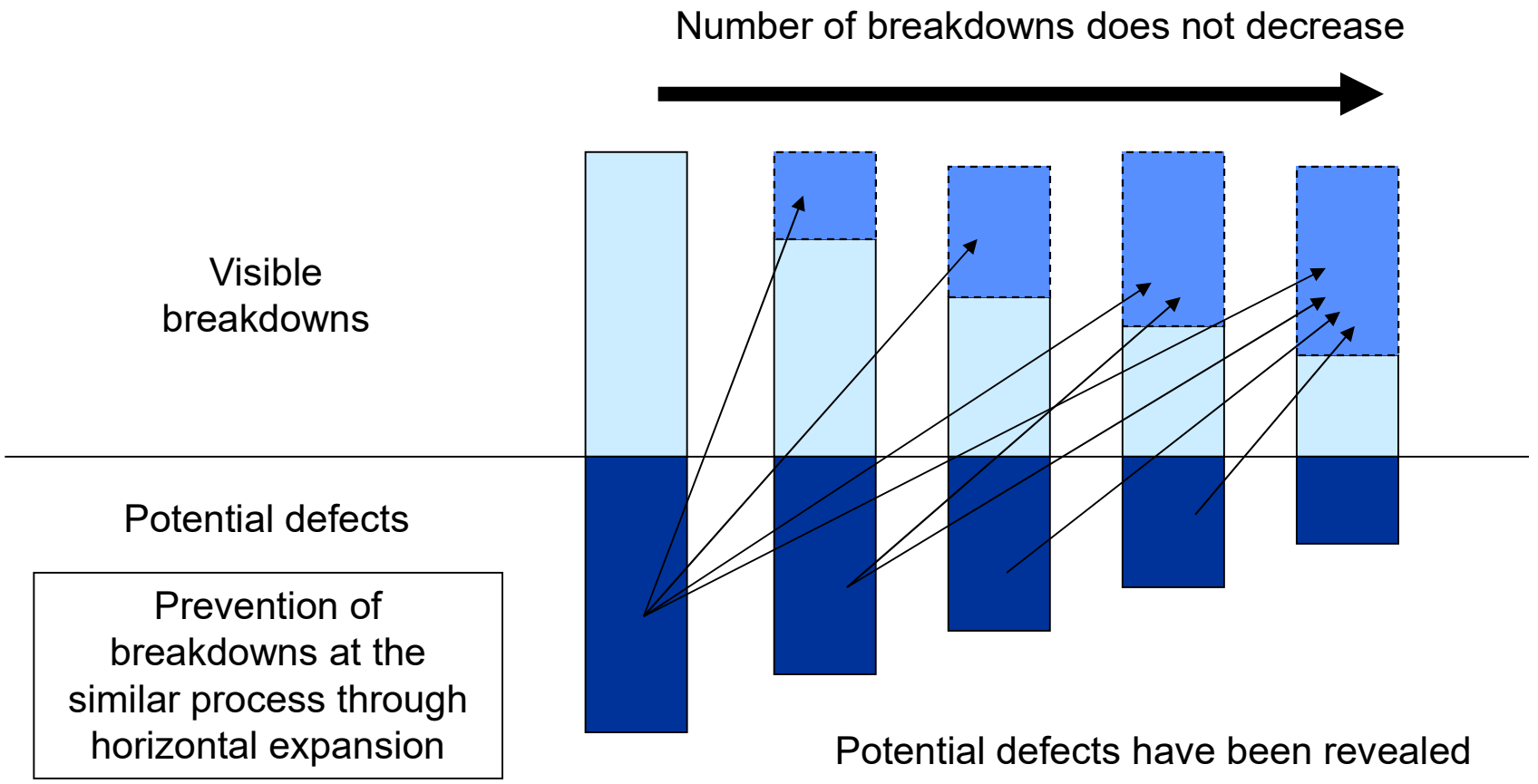
③ Technically hidden defects: Defects which have been unattended as designs weaknesses caused by insufficient technical checking

- Strain inside the shaft (catastrophic breakdown)
- These failures rarely take place and must be addressed by involving technical staff

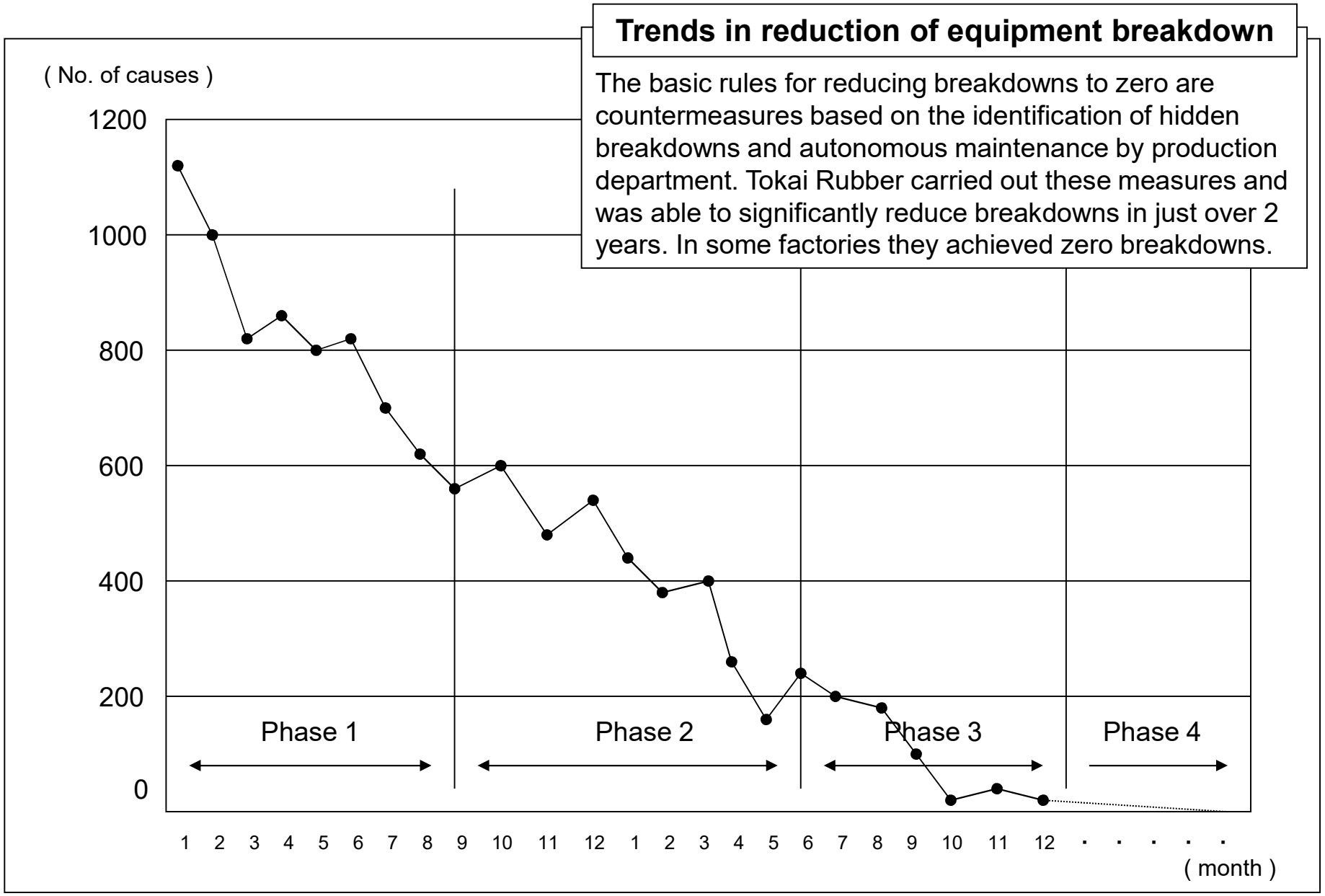
Identifying hidden defects



Revealing potential defects



Case – 1

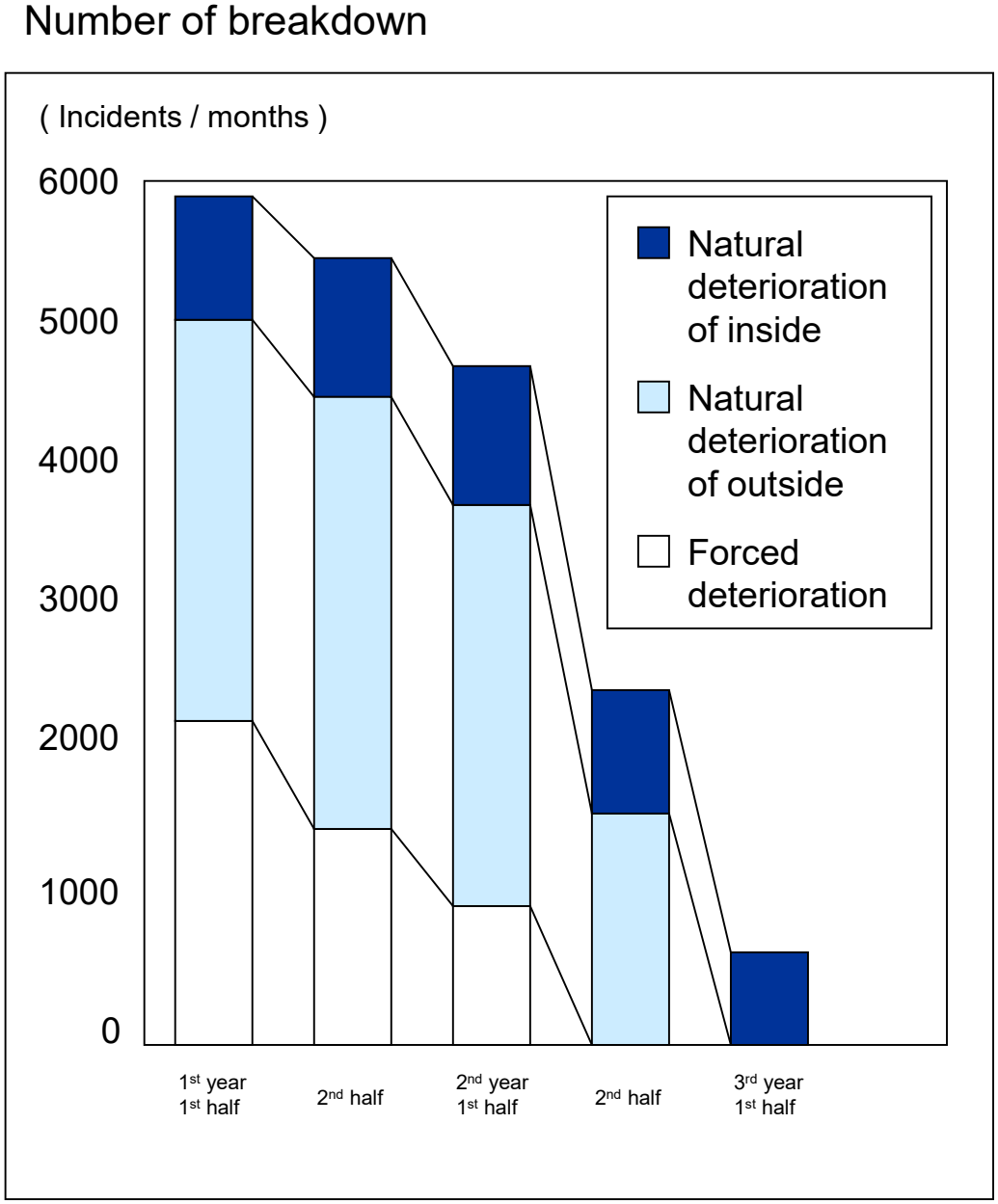

Trends in reduction of equipment breakdown
The basic rules for reducing breakdowns to zero are countermeasures based on the identification of hidden breakdowns and autonomous maintenance by production department. Tokai Rubber carried out these measures and was able to significantly reduce breakdowns in just over 2 years. In some factories they achieved zero breakdowns.
(No. of causes)
1200
1000
800
600
400
200
0
Phase 1
Phase 2
Phase 3
Phase 4
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 · · · · ·
(month)

Case – 2

Transition of the number of breakdowns at “ D company ”

Factory figures:

1. Maximum production capacity:
   32,000～35,000 units per month
2. Employees
   3,200 people
3. Number of equipment
   4,000 units
4. Production processes
   1st division: Machining, adjustment, pressing, plating
   2nd division: Plating, coating, assembly

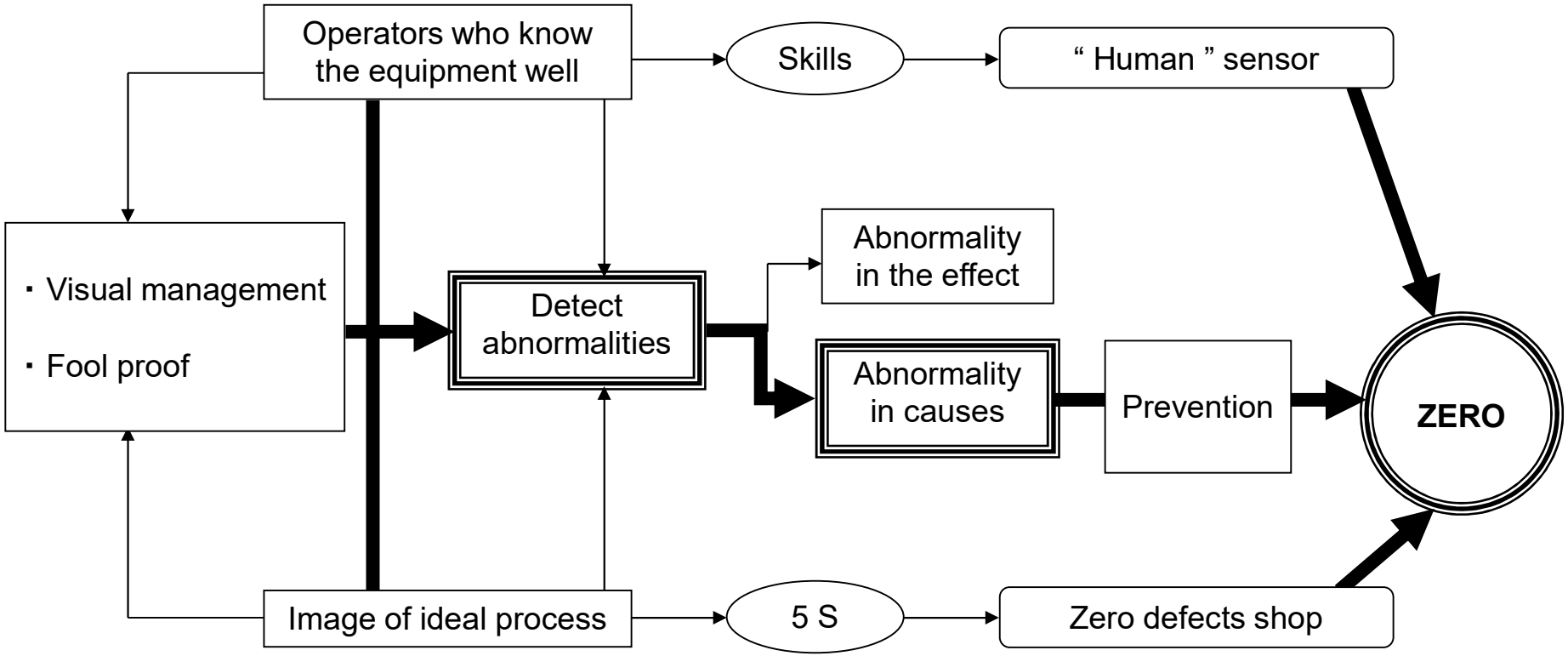


Problems in dealing with breakdowns in the factory

1. Superficial fixing, simple replacement of parts	・Merely repeating these measures will not lead to breakdown reduction. In particular, this tendency appears to be prevalent in middle-ranking maintenance personnel.
2. Causes of breakdown not examined in sufficient depth	・The real purpose of maintenance is to prevent reoccurrence. ・The most important method for reducing breakdowns and improving engineering and technical skills is to persistently try to find root causes, and find comprehensive measures to deal with each individual incident. ・Are we neglecting to confirm what happened and why, due to the need of restarting production as quickly as possible. ・It is important to develop the habit of a thorough examination of causes, with the cooperation of the production department
3. Ignoring minor breakdowns	・Failures should not be ignored even if they only occur for a few minutes. If small incidents occur repeatedly, they results in a big loss. Furthermore, minor breakdowns can be a precursor to a large failure.
4. No measures are being taken to eliminate human errors	・Just because a fault is due to a human error does not mean that the fault will be solved simply by passing it on to the production department. Measure to make sure the human errors do not occur and are not possible to occur must be taken with the cooperation of the production department.
5. Not making enough effort to apply solutions horizontally	・One breakdown suggests there may be potential failures in other similar areas. Speedy efforts must be made to find all similar areas, inspect them and address the problem with consistent measures.
6. Too much attention is paid to the breakdowns which have already occurred	・Although the most important thing is to take measures regarding the breakdowns which have occurred, most breakdowns occur through deterioration. ・Be fully aware that fundamental measures to prevent breakdowns consist of the following two measures: 1) Clarification of operating conditions and compliance to conditions in use to prevent forced deterioration. 2) Clarification of the gap between the current state of the equipment and its desired state in order to identify and resolve hidden defects.
7. Repair errors and the quality of repair are not clear	・Maintenance operators must be maintenance professionals. ・Clarify responsibilities for repair errors and preventing their reoccurrence. Taking countermeasures will improve engineering and technical ability. It is necessary to confirm the quality after repair. ・Attention must be paid to the finest details to such a level as, the tightening of each single bolt, the arrangement of every wire and the bending of each cotter pin. (Confirm the number of repair errors)
8. Not enough efforts are paid to chronic losses	

The importance of maintenance information

Creating the shop where abnormality can be detected audibly and visually upon its happening



Phase 1 (Reduce the number of breakdowns to half) — Step 1 to Step 3

Stabilize the interval between one breakdown and the next one

① Restore deterioration which has been left unattended

Priority must be given to addressing defects which are apparent but are not attended due to either a tight budget or the lack of motivation.

- Being left in use
- Being left loose
- Being left out of position
- Being left out of order

} Make a list → Take countermeasure

② Eliminate accelerated deterioration

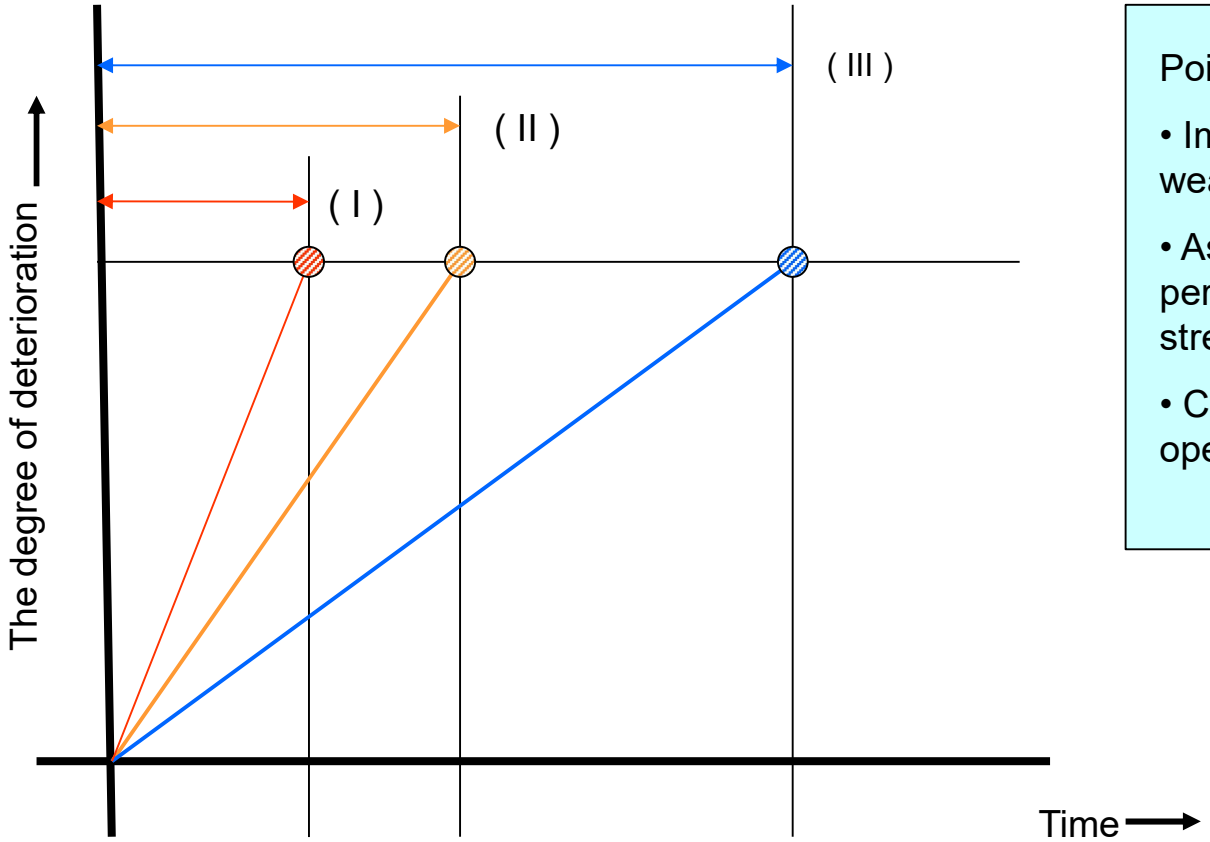
Abnormal deterioration caused by excessive stress above the designed level → Accelerated deterioration

(1) Maintain basic conditions – cleaning, lubricating, retightening

(2) Comply with conditions of use

- Prevention against external disturbances, such as vibration, noises, etc.
- Conditions appropriate for the specification of a unit or a part
  --- environmental conditions, appropriate load, method of attachment
- Loading conditions appropriate for the equipment's capability

Phase 2 : Lengthen Equipment Life Span



Points :

- Improvement of design weaknesses
- Assurance of higher performance against wear, stress and tenacity
- Countermeasures against operational stresses

Phase 2 : Lengthen Equipment Life Span

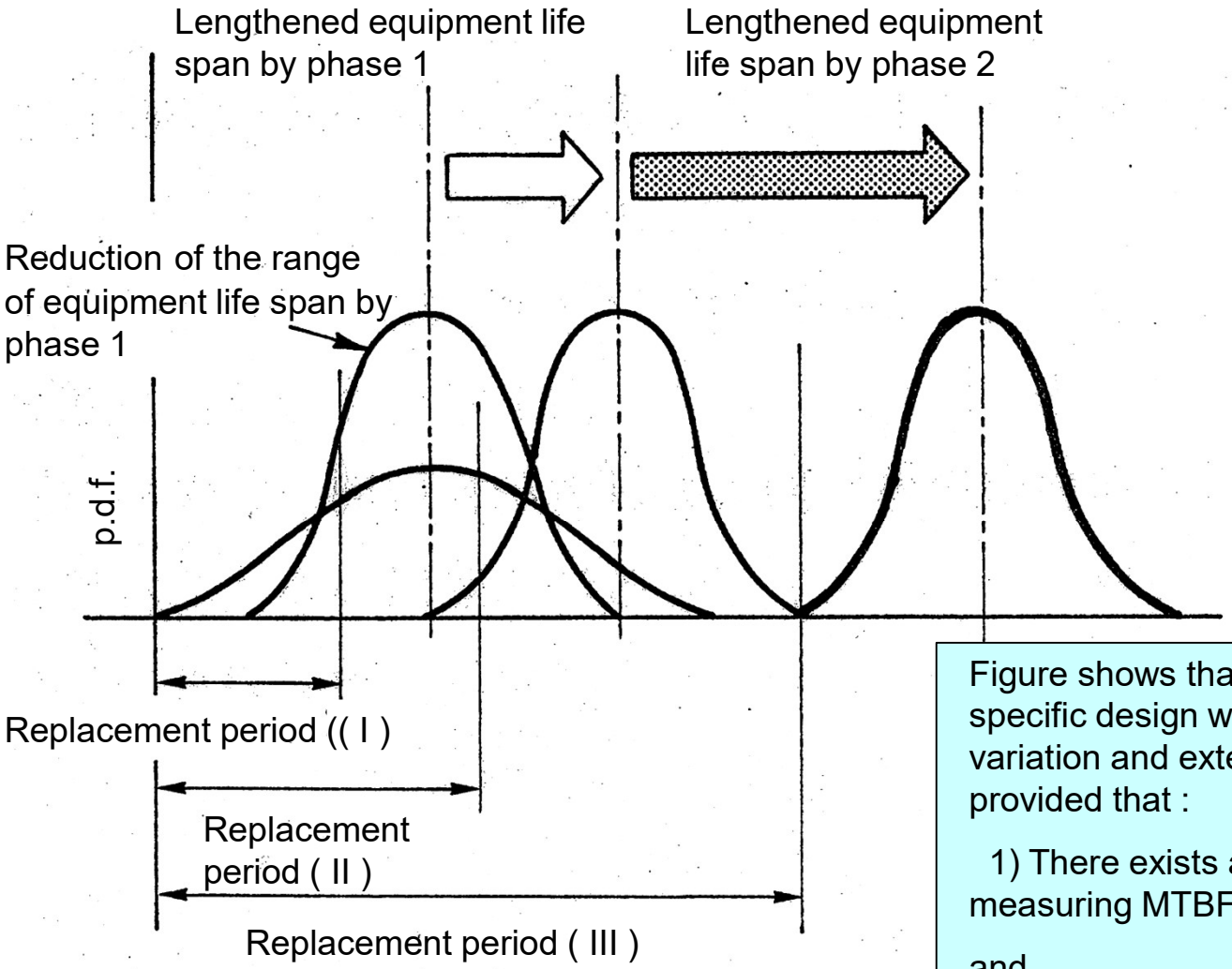


Figure : Lengthened equipment life span by phase 2

Figure shows that taking action against specific design weaknesses narrows the variation and extends life still further provided that :

1) There exists an equipment ledger measuring MTBF

and

2) There exists an engineering support to correct design weaknesses.

Phase 2 (Reduce the number of breakdown 1/5) — Step 4

Lengthen equipment lifespan

① Lengthen part lifespan

Where remaining life is short even where forced deterioration is excluded, an analysis of weak points can help prolong life

(1) Improve design weaknesses

- Lack of strength
- imperfections in installation.
- imperfections in processing

(2) Improve weaknesses against overloading

If the amount of load on the equipment cannot be reduced, strengthen the weakest point

(3) Select components appropriate for the conditions of use

② Eliminate chance failures

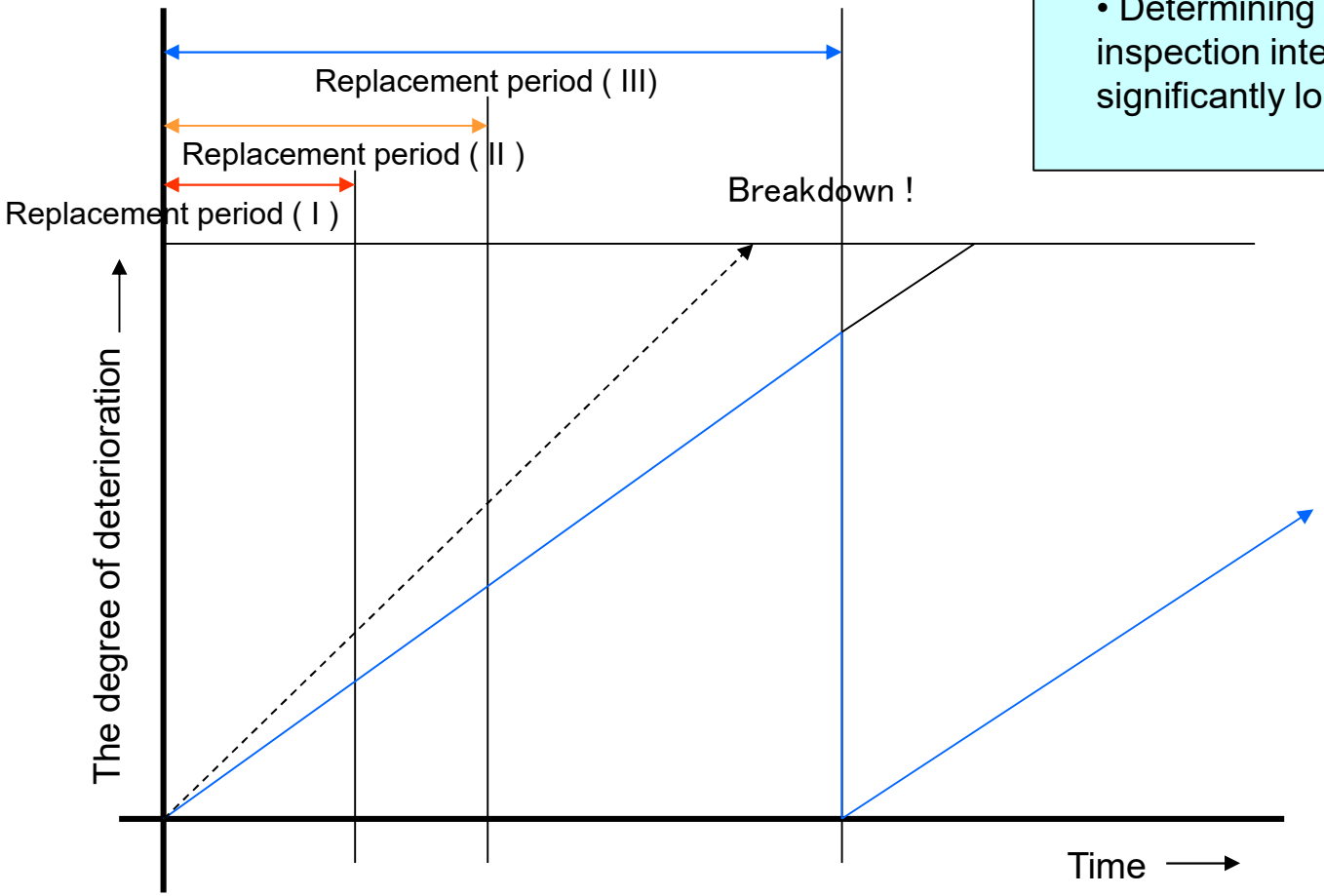
(1) Countermeasures against repair misses
- Acquire basic repair skills
- Improve repair methods, etc.

(2) Countermeasures against human errors
- Standardize methods of operation
- Attaching fool proof device, failsafe device, etc.

③ Restore external deterioration

General external inspection of hydraulic and pneumatic units, driving systems, electrical systems, etc. and restoration of deterioration

Phase 3 : Periodically Restore Deterioration



Points :

- Performing periodic reviewing and inspection
- Determining optimal reviewing and inspection intervals despite of significantly longer life

Phase 3 : Periodically Restore Deterioration

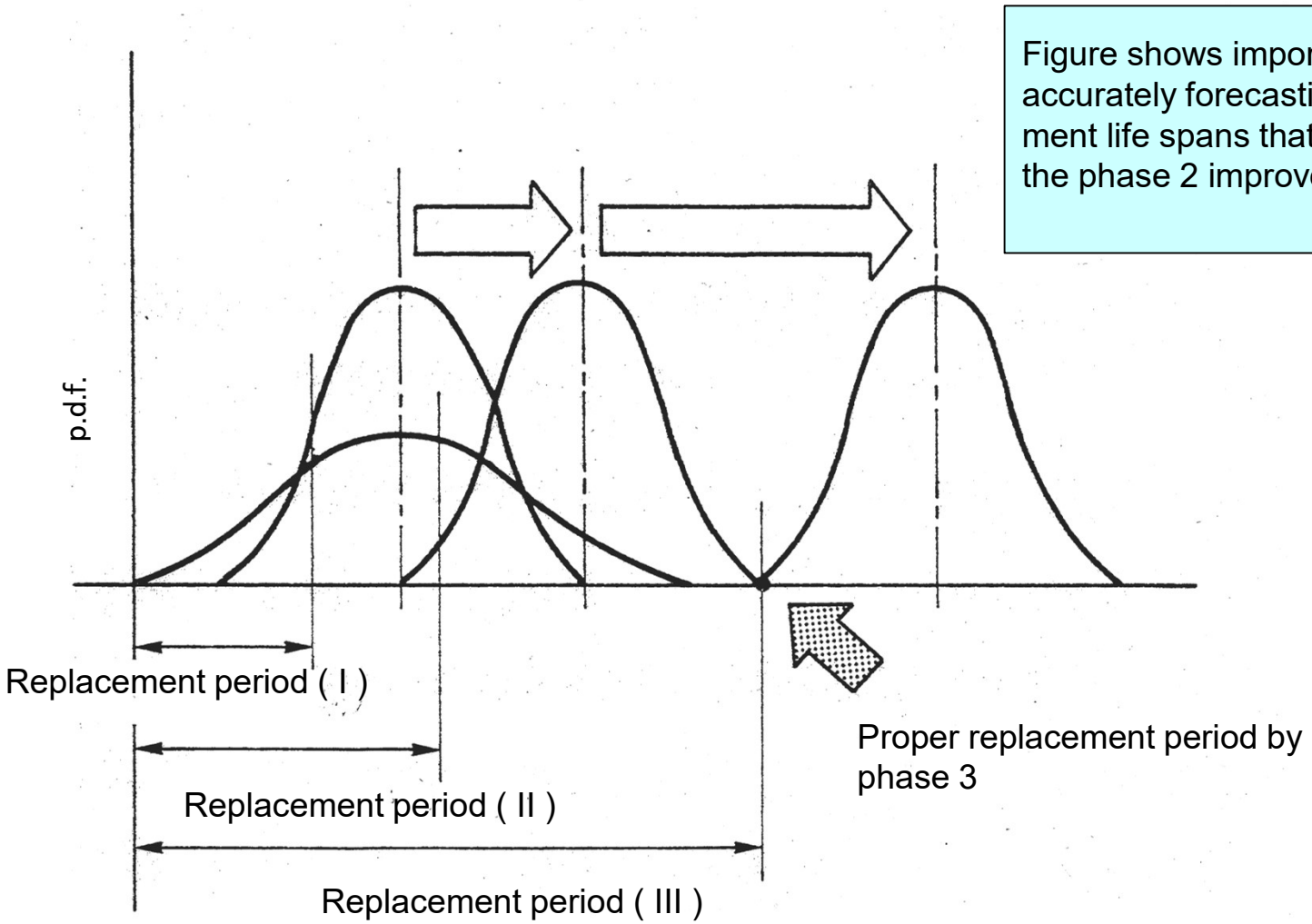


Figure : Proper replacement period by phase 3 of periodically restoring deterioration

Phase 3 (Reduce the number of breakdown 1/10) — Step 5

Restore periodically deteriorated parts

① Estimate MTBF and restore periodically deterioration

The first and second phases will extend MTBF and stabilize MTBF.
Therefore, the validity of periodic restoration will increase from the viewpoints of reliability and cost.

(1) Improve maintainability

Add structural improvements to equipment easier to maintain

- Use common parts
- Exchange blocks
- Simplify assembly and disassembly
- Improve jigs and tools and make them specialized
- Standardize spare parts

(2) Standardization and execution of periodic maintenance

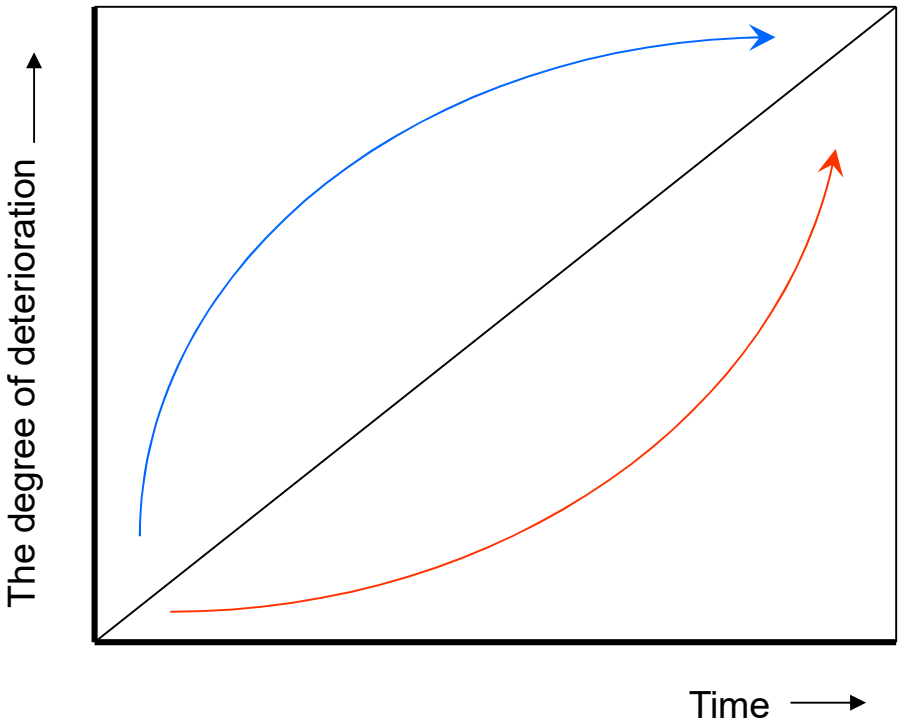
- Periodic inspection
- Periodic checks
- Periodic servicing

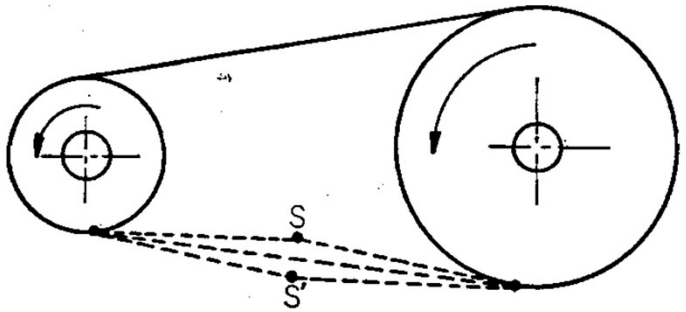
② Use five senses to grasp abnormalities indicating deterioration

If you have difficulty in determining the remaining life, or cannot eliminate a wide variation of the part lifespan, the only method is to detect early sign of failures

1) Before the breakdown occurred, were there any symptoms of any abnormalities?
2) Does this breakdown produce any early warning signs or not?
3) What early symptoms can lead to the discovery of this breakdown?
4) Why were we unable to detect the early symptoms of this breakdown?
5) What can we do to detect the early symptoms of the breakdown?
6) What knowledge and skills are necessary for the operator or notice the symptoms of the breakdown?

Phase 4 : Predict Breakdowns

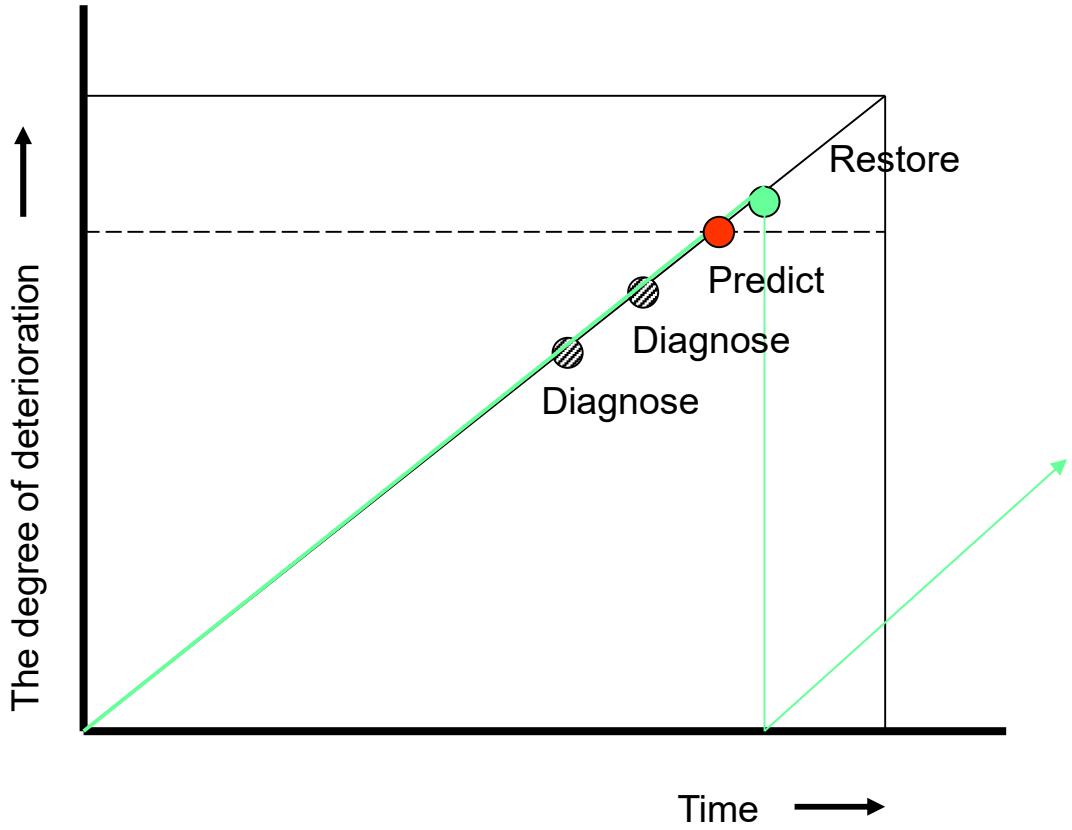




Points :

- Investigation of the deterioration pattern with the progress of time
- Physical analysis of deterioration
- Relationship between measurable deterioration and quality

Phase 4 : Predict Breakdowns



Points :

- Detection of parameters out of the deterioration pattern
- Selection of measuring methods from the chosen parameters
- Check how deterioration will appear in physical units such as dimension change, vibration by movement, consumed power, temperature rise, pressure change, magnet effect, etc.
- Trend management by a simple diagnosis technique
- Precision diagnosis after a turning point
- Development of a proper diagnosis technique
- Scheduled restoration

Phase 4 : Predict Breakdowns

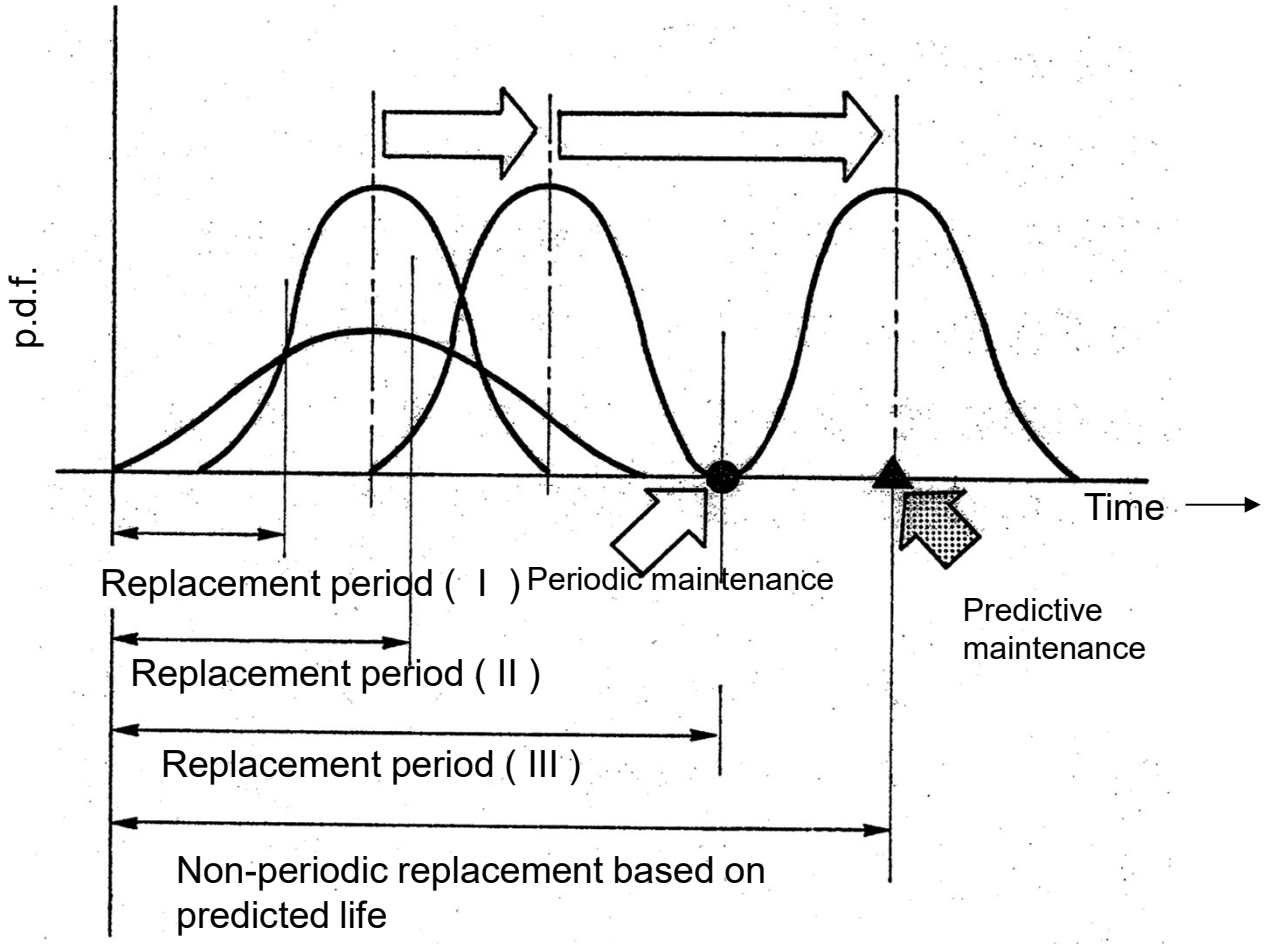


Figure : Non-periodic replacement based on predicted life by phase 4

Figure shows that predictive maintenance is the ideal, and potentially most profitable type of maintenance.

Phase 4 (Reducing the number of breakdowns to zero) — Step 6 to Step 7

Predict and extend equipment life times

①Prediction of breakdowns by applying equipment diagnosis techniques.

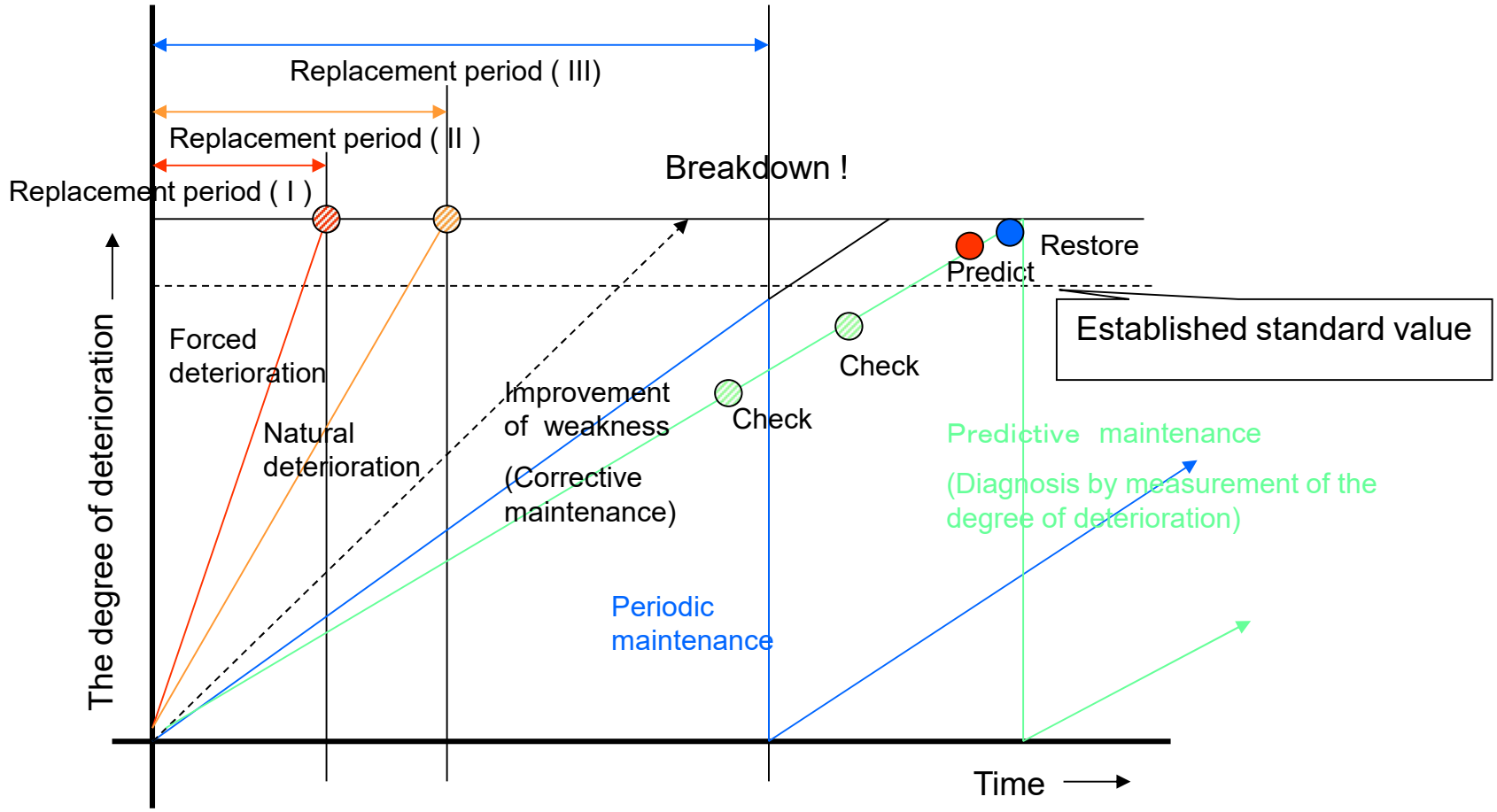
Deterioration pattern:
- ・Leaks
- ・Breakages
- ・Corrosion
- ・Abnormal sounds
- ・Abnormal temperature
- ・Abnormal vibration
- ・Material degradation
- ・Oil degradation
- ・Looseness
- ・Abnormalities in the electrical system

Measurement tool:
- ・Shock pulse meter
- ・Vibration measurement
- ・Measurement by ultrasonic sounds (AE method)
- ・Magnetic, X ray search
- ・Spectrographic analysis (SOAP method)
- ・Insulation measurement

②Estimate and lengthen the remaining life by using technical analysis for catastrophic breakdowns

(1) Analysis of a fractured cross section
Concentrated stress
(2) Analysis of material fatigue
Repetitive load
Alternative load …SN curve analysis
(3) Analysis of the gear tooth surface

Concept of Zero Equipment Breakdown



Zero Breakdowns in Four Phases

Phase 1

Stabilize mean time between failures (MTBF)

Restore unchecked deterioration

1. Establish basic conditions by cleaning, lubricating, and tightening.
2. Expose abnormalities and restore deterioration.
3. Clarify operating conditions and comply with conditions of use.

Prevent accelerated deterioration

4. Abolish environments causing accelerated deterioration (eliminate or control major contamination sources).
5. Establish daily checking and lubricating standards.
6. Introduce extensive visual controls.

Zero Breakdowns in Four Phases

Phase 2

Lengthen equipment life

Eliminate sporadic breakdowns

1. Evaluate equipment to select PM items (prioritize maintenance tasks).
2. Rank failures according to seriousness.
3. Prevent major breakdowns from recurring.
4. Eliminate unexpected failures by preventing operating and repair errors.
5. Upgrade adjustment and setting skills.

Correct design weaknesses

6. Correct weaknesses in strength and precision.
7. Select parts conformable to operating conditions.
8. Correct weaknesses to prevent overloading.

Zero Breakdowns in Four Phases

Phase 3

Periodically restore deterioration

Build a periodic maintenance system

1. Perform periodic servicing.
2. Perform periodic inspection.
3. Establish work standards.
4. Control spares.
5. Control data.
6. Improve maintainability.

Recognize process abnormality signs and detect abnormalities

7. Identify deterioration that gives warning signs.
8. Identify types of warning signs given.
9. Learn to detect warning signs.

Deal with abnormalities correctly

V-belt drives: Preventive maintenance procedures

Inspection (failure risks for not following the procedures below are noted along with a rating):

LOW: minimal risk/low chance of failure;

MEDIUM: failure is possible, and equipment not operating to specifications is highly probable;

HIGH: failure will happen prematurely.

- Check belt tension using a belt tension gauge. Measure the deflection and tension for the size of the belt. (Be sure to write tension and deflection specifications for the mechanic on the PM checklist.) Set tension on belt if deficiency noted.

Risk if the procedure is not followed: MEDIUM. Belt slippage will occur, thus resulting in equipment not operating to operation specifications. Another result from slippage is for belts to break, and the consequences be a fire or at least machine stoppage.

V-belt drives: Preventive maintenance procedures

- Identify any type of oil, grease, or chemical within 36 inches of belts (oil leakage from gearbox, motor, bearing, or chemicals from other sources). Write a corrective maintenance work order to repair leak or eliminate source of oil, grease, or chemical from the area.

  Risk if the procedure is not followed: HIGH. Belt slippage will occur, thus resulting in equipment not operating to operation specifications. Another result from slippage is for belts to break, and the consequences be a fire or at least machine stoppage.

- Check sheave alignment. If sheaves are not in alignment, align to manufacturer's specification. (Be sure to write the specification on this procedure; mechanics should not guess on this specification.)

  Risk if the procedure is not followed: MEDIUM. Rapid belt wear will occur, thus resulting in equipment not operating to specifications. The belts could break if cords in the belt, begin to break due to this misalignment.

V-belt drives: Preventive maintenance procedures

- Check sheaves for wear. Use a sheave gauge to ensure the sheave is not worn. If worn, write a corrective maintenance work order to change the sheave at a later date.

  Risk the procedure is not followed: HIGH. Belts will slip (even though you may not hear the slippage), thus resulting in equipment not operating to specifications

Chain drives: Preventive maintenance procedures

Inspection (risks of failures for not following the procedures below is noted along with a rating):

LOW: minimal risk/low chance of failure;

MEDIUM: failure is possible but equipment not operation to specification is highly probable;

HIGH: failure will happen prematurely.

- Inspect a chain for wear by inspecting the links for worn bushings. If worn bushings are noted, write a corrective maintenance work order so that the replacement can be planned and scheduled at a later time.

  Risk if the procedure is not followed: HIGH. Chain breakage will occur.

- Lubricate chain with lightweight oil recommended by chain manufacturer. (Ask your chain supplier to visit your site and make recommendations based on documentation they can present to you.)

  Risk if the procedure is not followed: HIGH. Chain breakage will occur.

Chain drives: Preventive maintenance procedures

- Check chain sag. Measure the chain sag using a straight edge or string and measure the specifications noted on this PM task. (The chain sag specification can be provided by your chain supplier, or you can use the procedure noted earlier in this chapter.) **WARNING**: The specification must be noted on the PM procedure.
- Set tension, and make a note at bottom of the PM work order, if a deficiency is noted.

Risk if the procedure is not followed: MEDIUM. Sprocket and chain wear will accelerate, thus casing equipment stoppage.

Chain drives: Preventive maintenance procedures

Inspect sprockets for worn teeth and abnormal wear on the sides of the sprockets. (The question is: Can the sprockets and chain last for two more weeks without equipment stoppage?) If the sprockets and chain can last two weeks then write a corrective maintenance work order in order for this job to be planned and scheduled with the correct parts. If the sprockets cannot last two weeks, then change all sprockets and the chain. Set and check sheave and chain alignment and tension. **WARNING**: When changing a sprocket, all sprockets, and the chain, should be changed because the difference between a worn and new sprocket in pitch diameter can be extreme, thus causing premature failure of the sprockets and chain.

Risk if the procedure is not followed: High. Worn sprockets are an indication of the equipment being in a failure mode. Action must be taken.

Zero Breakdowns in Four Phases

Phase 4

Predict equipment life

Build a predictive maintenance system

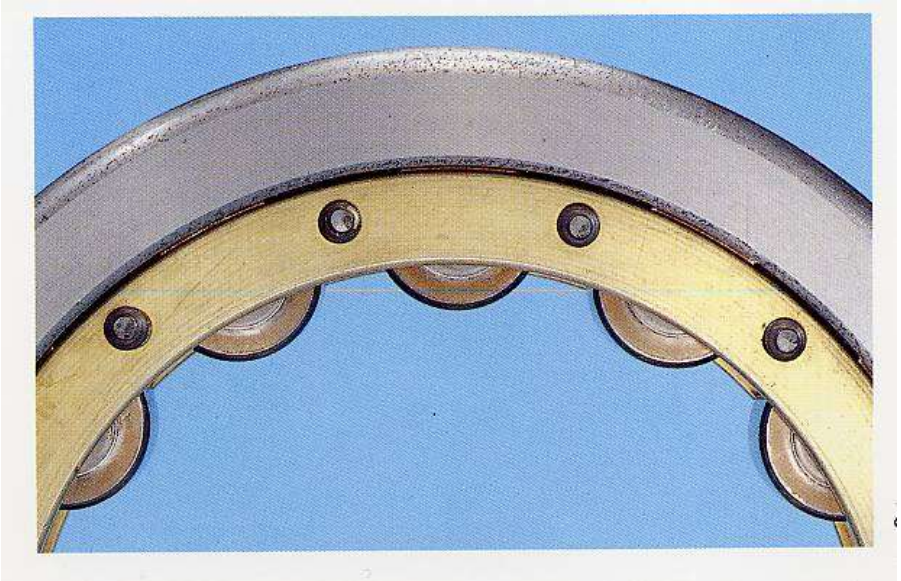
1. Clarify and adhere to operating standards.
2. Train equipment diagnosticians.
3. Introduce equipment diagnostic techniques.
4. Perform condition monitoring.

Consolidate improvement activities

5. Perform sophisticated failure analysis using specific engineering techniques.
   * Analyze rapture faces
   * Analyze material fatigue
   * Analyze gear tooth flanks, etc.
6. Extend equipment life by developing new materials and technology.

Damages and Countermeasures

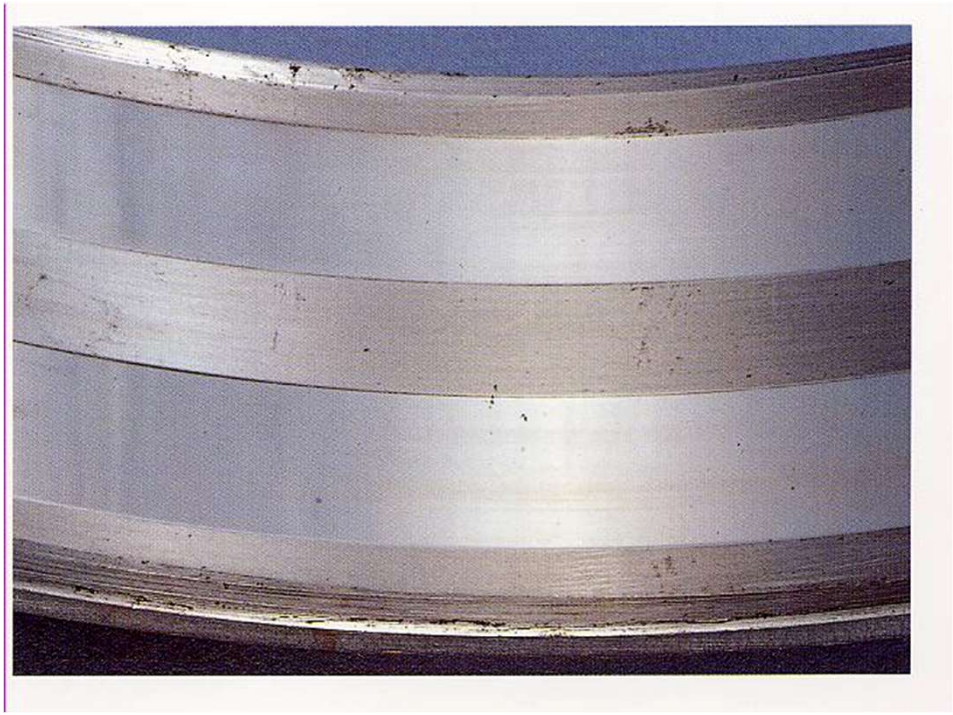
Damage of bearings



Wear on the edge of the roller

Damages and Countermeasures

Damage of bearings



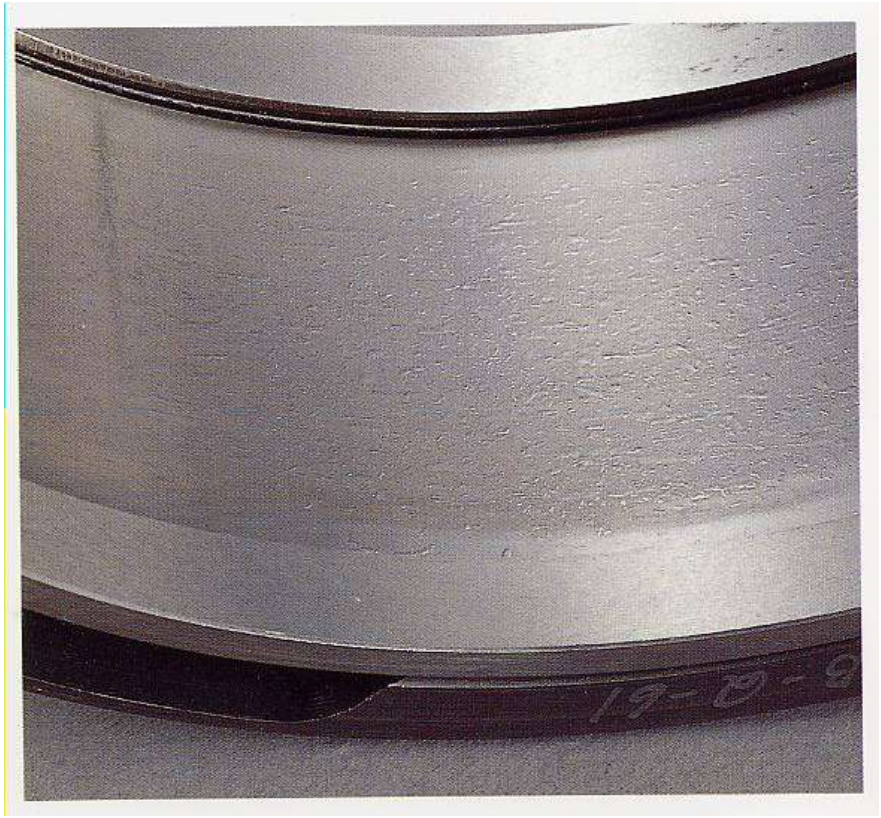
Wear on the outer rim

Damages and Countermeasures

Condition of wear	Cause	Countermeasures
Wear occurred on the sliding surface (collar surface, roller surface or pocket surface of a retainer)	Inappropriate or insufficient lubrication oil	• Review lubrication method or lubrication oil • Improve sealing devices • Thoroughly clean around the bearing
Wear occurred on the rim or rolling surface	• Invasion of foreign body • Inappropriate of insufficient lubrication oil	

Damages and Countermeasures

Damage of bearings



Satin finished surface of the outer rim

Damages and Countermeasures

Damage of bearings

Satin finish surface of the inner rim

Damages and Countermeasures

Condition of wear	Cause	Countermeasures
Impression like satin finish surface occurred on the rim or rolling surface	Main minute foreign body get in	• Thoroughly wash around the bearing • Improve the sealing devices and prevent foreign body from invasion

Damages and Countermeasures

Damage of toothed gears

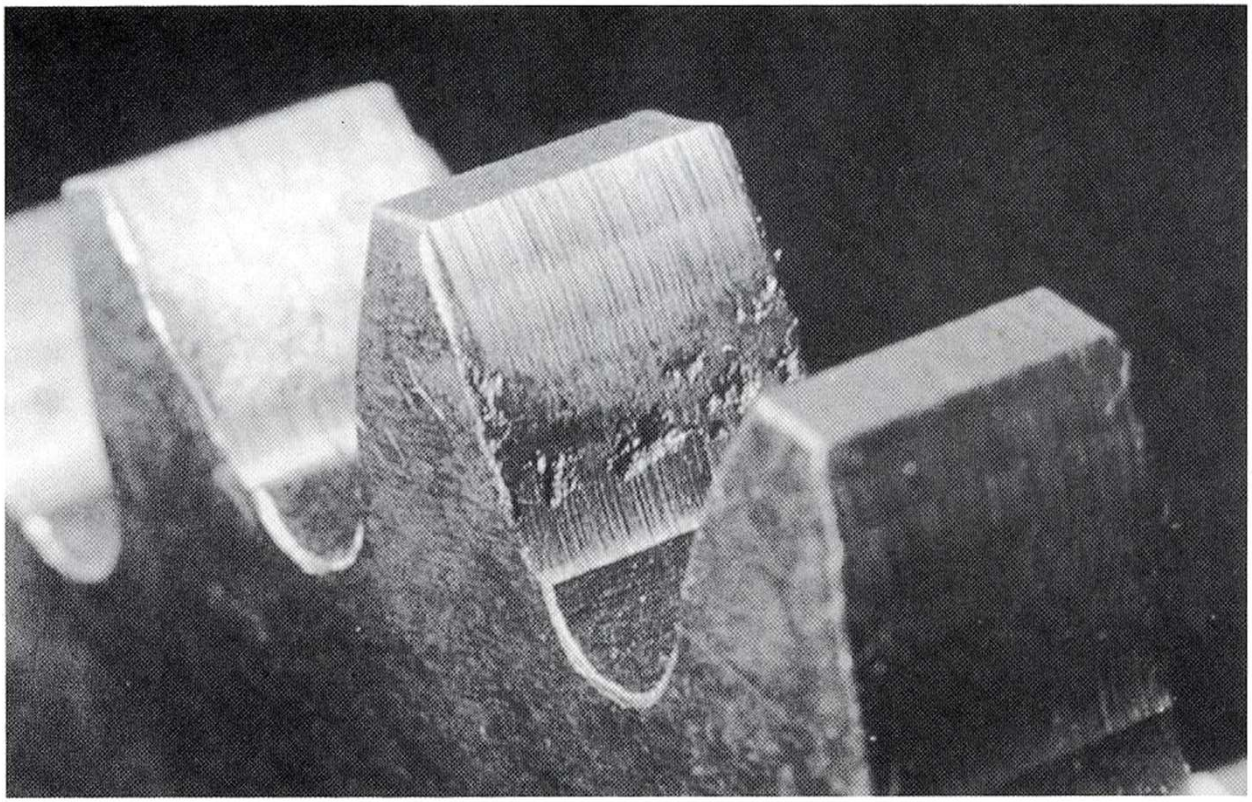
Excessive Wear

Damages and Countermeasures

Classification	Phenomenon	Cause
Deterioration of tooth surface wear	Although wear does not look serious from outside, actually the tooth surface is chipped away.	(1) In spite of the load imposed on the tooth and the roughness of the tooth surface, oil film is very thin. Thus the effect of lubrication is almost none, which causes severe metal contact repeatedly. (2) The existence of minute abrasive foreign body may also be the cause of the wear.

Damages and Countermeasures

Damage of toothed gears



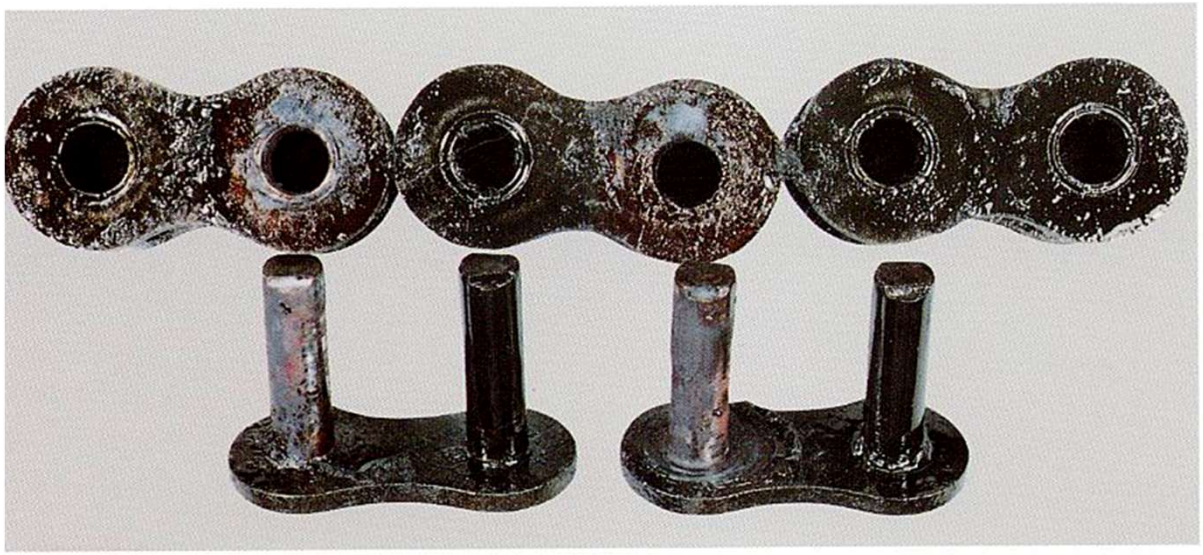
Scratching

Damages and Countermeasures

Classification	Phenomenon	Cause
Deterioration of tooth surface : wear	Deep and linear scratches appear parallel to the sliding direction of tooth surface.	(1) Solid foreign body with the diameter bigger than the thickness of the oil film between two tooth surfaces gets in. (2) The surface of a tooth is scratched against its opposite tooth surface with a built in foreign body.

Damages and Countermeasures

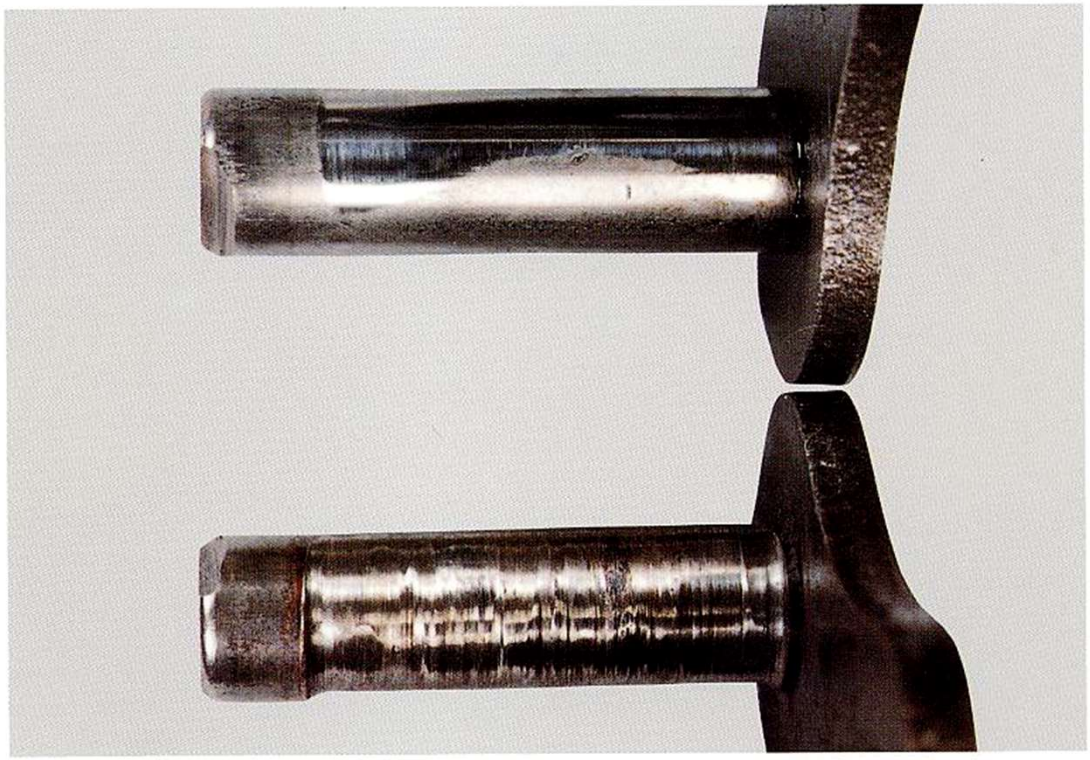
Damages of the chains



Insufficient oiling

Damages and Countermeasures

Damages of the chains



Insufficient oiling

Damages and Countermeasures

Symptoms/conditions of damages	Anticipated cause	Countermeasures
The wear takes place at a part of the chain. The chain is elongated and thus that part does not bend smoothly. The pin with lubrication oil is worn out, and the one without lubrication oil shows adhesion wear.	Insufficient oiling and uneven oiling condition.	Periodically supply the lubrication oil with proper viscosity.

Common failures modes of centrifugal pumps

	THE PROBLEM												
THE CAUSES	Insufficient Discharge Pressure	Intermittent Operation	Insufficient Capacity	No Liquid Delivery	High Bearing Temperature	Short Bearing Life	Short Mechanical Seal Life	High Vibration	High Noise Levels	Power Demand Excessive	Motor Trips	Elevated Motor Temperature	Elevated Liquid Temperature
Bent Shaft					●	●	●	●		●			
Casing Distorted form Excessive Pipe Strain					●	●	●	●		●		●	
Cavitation	●	●	●	●	●		●	●	●				●
Clogged Impeller	●		●	●				●		●			
Driver Imbalance						●	●	●					
Electrical Problems (Driver)						●	●	●		●	●	●	
Entrained Air (Suction or Seal Leaks)	●	●	●					●	●			●	
Hydraulic Instability					●	●	●	●	●				
Impeller Installed Backward (Double-Suction Only)	●		●							●			
Improper Mechanical Seal							●						

Common failures modes of centrifugal pumps

	THE PROBLEM												
THE CAUSES	Insufficient Discharge Pressure	Intermittent Operation	Insufficient Capacity	No Liquid Delivery	High Bearing Temperature	Short Bearing Life	Short Mechanical Seal Life	High Vibration	High Noise Levels	Power Demand Excessive	Motor Trips	Elevated Motor Temperature	Elevated Liquid Temperature
Inlet Strainer Partially Clogged	●		●					●	●				●
Insufficient Flow through Pump													●
Insufficient Suction Pressure (NPSH)	●	●	●	●				●	●				
Insufficient Suction Volume	●	●	●	●	●			●	●				●
Internal Wear	●		●					●		●			
Leakage in Piping, Valves, Vessels	●		●	●									
Mechanical Defects, Worn, Rusted, Defective Bearings					●		●			●			
Misalignment					●	●	●	●		●		●	
Misalignment (Pumps and Driver)								●		●	●		●
Misalignment Pumps in Series	●		●			●		●		●			

Common failures modes of centrifugal pumps

	THE PROBLEM												
THE CAUSES	Insufficient Discharge Pressure	Intermittent Operation	Insufficient Capacity	No Liquid Delivery	High Bearing Temperature	Short Bearing Life	Short Mechanical Seal Life	High Vibration	High Noise Levels	Power Demand Excessive	Motor Trips	Elevated Motor Temperature	Elevated Liquid Temperature
Noncondensables in Liquid	●	●	●					●	●			●	
Obstructions in Lines or Pump Housing	●		●	●				●				●	●
Rotor Imbalance						●	●	●					
Specific Gravity Too High	●									●		●	
Speed Too High										●	●		
Speed Too Low	●		●	●								●	
Total System Head Higher Than Design	●	●	●	●	●		●					●	●
Total System Head Lower Than Design					●		●	●	●	●			●
Unsuitable Pumps in Parallel Operation	●		●	●	●			●	●		●		●
Viscosity Too High	●		●							●		●	
Wrong Rotation	●			●						●		●	

Common failures modes of rotary-type, positive-displacement pumps

	THE PROBLEM										
THE CAUSES	No Liquid Delivery	Insufficient Discharge Pressure	Insufficient Capacity	Starts, But Loses Prime	Excessive Wear	Excessive Heat	Excessive Vibration and Noise	Excessive Power Demand	Motor Trips	Elevated Motor Temperature	Elevated Liquid Temperature
Air Leakage into Suction Piping or Shaft Seal		●	●				●			●	
Excessive Discharge Pressure			●		●		●	●	●		●
Excessive Suction Liquid Temperatures			●	●							
Insufficient Liquid Supply		●	●	●	●		●		●		
Internal Component Wear	●	●	●				●				
Liquid More Viscous Than Design								●	●	●	●
Liquid Vaporizing in Suction Line		●	●	●			●				●
Misaligned Coupling, Belt Drive, Chain Drive					●	●	●	●		●	
Motor or Driver Failure	●										

Common failures modes of rotary-type, positive-displacement pumps

	THE PROBLEM										
THE CAUSES	No Liquid Delivery	Insufficient Discharge Pressure	Insufficient Capacity	Starts, But Loses Prime	Excessive Wear	Excessive Heat	Excessive Vibration and Noise	Excessive Power Demand	Motor Trips	Elevated Motor Temperature	Elevated Liquid Temperature
Pipe Strain on Pump Casing					●	●	●	●		●	
Pump Running Dry	●	●			●	●	●				
Relief Valve Stuck Open or Set Wrong		●	●								
Rotating Element Binding					●	●	●	●	●	●	
Solids or Dirt in Liquid					●						
Speed Too Low		●	●						●		
Suction Filter or Strainer Clogged	●	●	●				●			●	
Suction Piping Not Immersed Liquid	●	●		●							
Wrong Direction of Rotation	●	●								●	

Common failures modes of reciprocating positive-displacement pumps

	THE PROBLEM								
THE CAUSES	No Liquid Delivery	Insufficient Capacity	Short Packing Life	Excessive Wear Liquid End	Excessive Wear Power End	Excessive Heat Power End	Excessive Vibration and Noise	Persistent Knocking	Motor Trip
Abrasives or Corrosives in Liquid			●	●					
Broken Valve Springs		●		●			●		
Cylinders Not Filling		●	●	●			●		
Drive-Train Problems							●		●
Excessive Suction Lift	●	●							
Gear Drive Problem							●	●	●
Improper Packing Selection			●						
Inadequate Lubrication						●	●		●
Liquid Entry into Power End of Pump						●			
Loose Cross-Head Pin or Crank Pin								●	
Loose Piston or Rod								●	
Low Volumetric Efficiency		●	●						
Misalignment of Rod or Packing			●						●

Common failures modes of reciprocating positive-displacement pumps

	THE PROBLEM								
THE CAUSES	No Liquid Delivery	Insufficient Capacity	Short Packing Life	Excessive Wear Liquid End	Excessive Wear Power End	Excessive Heat Power End	Excessive Vibration and Noise	Persistent Knocking	Motor Trip
Non-Condensables (Air) in Liquid	●	●	●				●		●
Not Enough Suction Pressure	●	●							
Obstructions in Lines	●						●		●
One or More Cylinders Not Operating		●							
Other Mechanical Problems: Wear, Rusted, etc.					●	●	●	●	
Overloading					●				●
Pump Speed Incorrect		●				●			
Pump Valve(s) Stuck Open		●							
Relief or Bypass Valve(s) Leaking		●							
Scored Rod or Plunger		●							●
Supply Tank Empty	●								
Worn Cross-Head or Guides			●			●			
Worn Valves, Seats, Liners, Rods, or Plungers	●	●		●					

Common failures modes of centrifugal fans

	THE PROBLEM									
THE CAUSES	Insufficient Discharge Pressure	Intermittent Operation	Insufficient Capacity	Overheated Bearings	Shot Bearing Life	Overload on Driver	High Vibration	High Noise Levels	Power Damaged Excessive	Motor Trips
Abnormal End Thrust				●			●			
Aerodynamic Instability		●	●	●	●		●	●		
Air Leaks in System	●	●	●							
Bearings Improperly Lubricated						●	●	●		●
Bent Shaft				●	●	●	●		●	
Broken or Loose Bolts or Setscrews				●			●			
Damaged Motor							●			
Damaged Wheel	●		●	●						
Dampers or Variable-Inlet Not Properly Adjusted	●		●							
Dirt in Bearings				●			●			
Excessive Belt Tension				●			●			●
External Radiated Heat				●						

Common failures modes of centrifugal fans

	THE PROBLEM									
THE CAUSES	Insufficient Discharge Pressure	Intermittent Operation	Insufficient Capacity	Overheated Bearings	Shot Bearing Life	Overload on Driver	High Vibration	High Noise Levels	Power Damaged Excessive	Motor Trips
Fan Delivering More Than Rated Capacity						●	●			
Fan Wheel or Driver Imbalanced				●			●			
Foreign Material in Fan Causing Imbalance (Plate-out)				●			●	●		
Incorrect Direction of Rotation	●		●			●	●			
Insufficient Belt Tension							●	●		
Loose Dampers or Variable-Inlet Vanes							●			
Misaligment of Bearings, Coupling, Wheel, or Belts				●		●	●	●	●	
Motor Improperly Wired						●	●	●		●
Packing Too Tight or Defective Stuffing Box						●	●		●	●
Poor Fan Inlet or Outlet Conditions	●		●							
Specific Gravity or Density Above Design						●	●		●	
Speed Too High		●		●	●	●	●			●

Common failures modes of centrifugal fans

	THE PROBLEM									
THE CAUSES	Insufficient Discharge Pressure	Insufficient Operation	Insufficient Capacity	Overheated Bearings	Shot Bearing Life	Overload on Driver	High Vibration	High Noise Levels	Power Damaged Excessive	Motor Trips
Speed Too Low	●	●	●					●		●
Too Much Grease in Ball Bearings				●						
Total System Head Greater Than Design	●		●	●		●			●	
Total System Head Less Than Design		●					●			●
Unstable Foundation		●		●			●	●		
Vibration Transmitted to Fan from Outside Sources				●			●	●		
Wheel Binding on Fan Housing				●		●	●	●		●
Wheel Mounted Backward on Shaft	●			●						
Worn Bearings							●	●		
Worn Couplings							●			
120-Cycle Magnetic Hum							●	●		

Common failures modes of blowers and fluidizers

	THE PROBLEM									
THE CAUSES	No Air/Gas Delivery	Insufficient Discharge Pressure	Insufficient Capacity	Excessive Wear	Excessive Heat	Excessive Vibration and Noise	Excessive Power Demand	Motor Trips	Elevated Motor temperature	Elevated Air/Gas Temperature
Air Leakage into Suction Piping or Shaft Seal		●	●			●				
Coupling Misaligned				●	●	●	●		●	
Excessive Discharge Pressure			●	●		●	●	●		●
Excessive Inlet Temperature/Moisture			●							
Insufficient Suction Air/Gas Supply		●	●	●		●		●		
Internal Component Wear	●	●	●							
Motor or Driver Failure	●									
Pipe Strain on Blower Casing				●	●	●	●		●	
Relief Valve Stuck Open or Set Wrong		●	●							
Rotating Element Binding				●	●	●	●	●	●	
Solids or Dirt in Inlet Air/Gas Supply				●						
Speed Too Low		●	●					●		
Suction Filter or Strainer Clogged	●	●	●			●			●	
Wrong Direction of Rotation	●	●							●	

Common failures modes of pneumatic conveyors

	THE PROBLEM						
THE CAUSES	Fails to Deliver Rated Capacity	Output Exceed Rated Capacity	Frequent Fan/Blower Motor Trips	Product Contamination	Frequent System Blockage	Fan/Blower Failures	Fan/Blower Bearing Failures
Aerodynamic Imbalance			●			●	●
Blockage Caused By Compaction of Product	●		●			●	
Contamination in Incoming Product				●			
Excessive Moisture in Product/Piping	●		●	●	●	●	
Fan/Blower Too Small	●		●			●	
Foreign Object Blocking Piping	●		●		●		
Improper Lubrication						●	●
Mechanical Imbalance						●	●

Common failures modes of pneumatic conveyors

	THE PROBLEM						
THE CAUSES	Fails to Deliver Rated Capacity	Output Exceed Rated Capacity	Frequent Fan/Blower Motor Trips	Product Contamination	Frequent System Blockage	Fan/Blower Failures	Fan/Blower Bearing Failures
Misalignment						●	●
Piping Configuration Unsuitable	●		●		●		
Piping Leakage	●			●			
Product Compaction During Downtimes/Stoppage	●		●		●		
Product Density Too Great	●		●			●	
Product Density Too Low		●					
Rotor Binding or Contacting			●			●	●
Startup Torque Too Great			●				

Common failures modes of hefler-type chain conveyors

	THE PROBLEM							
THE CAUSES	Failure to Deliver Rated Capacity	Frequent Drive Motor Trips	Conveyor Blockage	Abnormal Wear on Drive Gears	Excessive Share Pin Breakage	Excessive Bearing Failures/Wear	Motor Overheats	Excessive Noise
Blockage of Conveyor Ductwork	●	●					●	
Chain Misaligned			●		●	●	●	●
Conveyor Chain Binding on Ductwork								●
Conveyor Not Emptied Before Shutdown		●	●		●			
Conveyor Over-Filled When Idle		●	●		●			
Excessive Looseness on Drive Chains	●							
Excessive Moisture in Product	●	●	●					
Foreign Object Obstructing Chain	●	●				●	●	
Gear Set Center-to-Center Distance Incorrect				●				●
Gears Misaligned				●		●	●	●
Lack of Lubrication				●		●	●	●
Motor Speed Control Damaged or Not Calibrated	●							
Product Density Too High	●	●			●		●	
Too Much Volume/Load	●	●					●	

Common failures modes of centrifugal compressors

	THE PROBLEM								
THE CAUSES	Excessive Vibration	Compressor Surges	Loss of Discharge Pressure	Low Lube Oil Pressure	Excessive Bearing Oil Drain Temp.	Units Do Not Stay in Alignment	Pressure Unloading	Water in Lube Oil	Motor Trips
Bearing Lube Oil Orifice Missing or Plugged				●					
Bent Rotor (Caused by Uneven Heating and Cooling)	●						●		
Build-up of Deposits on Diffuser		●							
Build-up of Deposits on Rotor	●	●							
Change in System Resistance		●							●
Clogged Oil Strainer/Filter				●					
Compressor Not Up to Speed			●						
Condensate in Oil Reservoir								●	
Damaged Rotor	●								
Dry Gear Coupling	●								
Excessive Bearing Clearance	●								
Excessive Inlet Temperature			●						
Failure of Both Main and Auxiliary Oil Pumps				●					
Faulty Temperature Gauge or Switch				●	●				●

Common failures modes of centrifugal compressors

	THE PROBLEM								
THE CAUSES	Excessive Vibration	Compressor Surges	Loss of Discharge Pressure	Low Lube Oil Pressure	Excessive Bearing Oil Drain Temp.	Units Do Not Stay in Alignment	Pressure Unloading	Water in Lube Oil	Motor Trips
Improperly Assembled Parts	●						●		●
Incorrect Pressure Control Valve Setting				●					
Insufficient Flow		●							
Leak in Discharge Piping			●						
Leak in Lube Oil Cooler Tubes or Tube Sheet								●	
Leak in Oil Pump Suction Piping				●					
Liquid “Slugging”	●						●		
Loose or Broken Bolting	●								
Loose Rotor Parts	●								
Oil Leakage				●					
Oil Pump Suction Plugged				●					
Oil Reservoir Low Level				●					
Operating at Low Speed w/o Auxiliary Oil Pump				●					

Common failures modes of centrifugal compressors

	THE PROBLEM								
THE CAUSES	Excessive Vibration	Compressor Surges	Loss of Discharge Pressure	Low Lube Oil Pressure	Excessive Bearing Oil Drain Temp.	Units Do Not Stay in Alignment	Pressure Unloading	Water in Lube Oil	Motor Trips
Operating in Critical Speed Range	●								
Operating in Surge Region	●								
Piping Strain	●					●	●	●	●
Poor Oil Condition					●				
Relief Valve Improperly Set or Stuck Open				●					
Rotor Imbalance	●						●		
Rough Rotor Shaft Journal Surface					●		●		●
Shaft Misalignment	●					●			
Sympathetic Vibration	●						●	●	
Vibration					●				
Warped Foundation or Baseplate							●		●
Wiped or Damaged Bearings					●				●
Worn or damaged Coupling	●								

Common failures modes of tottery-type, positive-displacement compressors

	THE PROBLEM									
THE CAUSES	No Air/Gas Delivery	Insufficient Discharge Pressure	Insufficient Capacity	Excessive Wear	Excessive Heat	Excessive Vibration and Noise	Excessive Power Demand	Motor Trips	Elevated Motor Temperature	Elevated Air/Gas Temperature
Air Leakage Into Suction Piping or Shaft Seal		●	●		●					
Coupling Misaligned				●	●	●	●		●	
Excessive Discharge Pressure			●	●		●	●	●		●
Excessive Inlet Temperature/Moisture			●							
Insufficient Suction Air/Gas Supply		●	●	●		●		●		
Internal Component Wear	●	●	●							
Motor or Drive Failure	●									
Pipe Strain on Compressor Casing				●	●	●	●		●	
Relief Valve Stuck Open or Set Wrong		●	●							
Rotating Element Binding				●	●	●	●	●	●	
Solid or Dirt in Inlet Air/Gas Supply				●						
Speed Too Low		●	●					●		
Suction Filter or Strainer Clogged	●	●	●			●			●	
Wrong Direction of Rotation	●	●							●	

Common failures modes of reciprocating compressors

	THE PROBLEM																							
THE CAUSES	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Air Discharge Temperature Too High		●																●						
Air Filter Defective		●																	●	●				●
Air Flow to Fan Blocked	●	●				●																		
Air leak into Pump Suction							●																	
Ambient Temperature Too High	●	●				●									●									
Assembly Incorrect																								●
Bearing Need Adjustment or Renewal					●	●	●								●									
Belts Slipping					●				●	●														
Belts Too Tight			●			●									●									
Centrifugal Pilot Valve Leaks																●								
Check or Discharge Valve Defective						●																		

Common failures modes of reciprocating compressors

THE CAUSES	THE PROBLEM																							
	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Control Air Filter, Strainer Clogged				●																				
Control Air Line Clogged																					●			
Control Air Pipe Leaks																					●	●		
Crankcase Oil Pressure Too High																●								
Crankshaft End Play Too Great					●																			
Cylinder, Heat, Cooler Dirty	●	●																						
Cylinder, Head, Intercooler Dirty						●												●						
Cylinder (Piston) Worn or Scored	●	●			●	●		●	●	●		H ●	L ●	H ●	L ●	●	●		H ●	H ●				
Detergent Oil Being Used (3)								●																
Demand Too Steady (2)																							●	
Dirt, Rust Entering Cylinder		●																	●	●				●

Common failures modes of reciprocating compressors

	THE PROBLEM																							
THE CAUSES	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Discharge Line Restricted	●														●									
Discharge Pressure Above Rating	●	●			●	●			●		●	●		●	●		●	●	●	●	●	●		
Electrical Conditions Wrong			●												●									
Excessive Number of States															●									
Excitation Inadequate			●												●									
Foundation Bolts Loose					●						●													
Foundation Too Small											●													
Foundation Uneven-Unit Rocks					●						●													
Fuses Blown			●																					
Gaskets Leak	●	●			●	●			●	●		H ●	L ●	H ●	L ●		●		H ●	H ●				
Gauge Defective							●			●		●	●								●			

Common failures modes of reciprocating compressors

	THE PROBLEM																							
THE CAUSES	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Gear Pump Worn/Defective							●																	
Grout, Improperly Placed											●													
Intake Filter Cogged	●				●	●			●	●			●		●	●	●							
Intake Pipe Restricted, Too Small, Too Long	●				●	●			●	●			●		●	●	●							
Intercooler, Drain More Often								●																
Intercooler Leaks													●											
Intercooler Passage Clogged												●		●										
Intercooler Pressure Too High																		●						
Intercooler Vibrating					●																			
Leveling Wedges Left Under Compressor											●													
Liquid Carry-Over					●			●											●	●				●

Common failures modes of reciprocating compressors

	THE PROBLEM																						
THE CAUSES	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Location Too Humid and Damp								●																
Low Oil Pressure Relay Open			●																					
Lubrication Inadequate	●				●	●									●		●		●	●				●
Motor Overload Relay Tripped			●																					
Motor Rotor Loose on Shaft					●							●												
Motor Too Small			●												●									
New Valve on Worn Seat																								●
“Off” Time Insufficient	●	●				●																		
Oil Feed Excessive		●			●															●				●
Oil Filter or Strainer Clogged							●																	
Oil Level Too High	●	●			●	●										●								

Common failures modes of reciprocating compressors

THE CAUSES	THE PROBLEM																							
	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Oil Level Too Low						●	●																	
Oil Relief Valve Defective							●																	
Oil Viscosity Incorrect		●			●	●	●								●	●			●	●				●
Oil Wrong Type																●								
Packing Rings Worn, Stuck, Broken																				●				
Piping Improperly Supported											●													
Piston or Piston Nut Loose					●																			
Piston or Ring Drain Hole Clogged																●								
Piston Ring Gaps Not Staggered																●								
Piston Rings Worn, Broken, or Stuck	●	●			●	●		●	●	●		H ●	L ●	H ●	L ●	●	●		H ●	H ●				
Piston-to-Head Clearance Too Small					●																			

Common failures modes of reciprocating compressors

THE CAUSES	THE PROBLEM																							
	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Pulley or Flywheel Loose					●						●													
Receiver, Drain More Often																							●	
Receiver Too Small																							●	
Regulation Piping Clogged				●																				
Resonant Pulsation (Inlet or Discharge)												●	●	●	●									●
Rod Packing Leaks	●				●	●			●	●														
Rod Packing Too Tight						●																		
Rod Scored, Pitted, Worn																				●				
Rotation Wrong	●	●	●																					
Runs Too Little (2)								●																
Safety Valve Defective													●	●								●		

Common failures modes of reciprocating compressors

	THE PROBLEM																							
THE CAUSES	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Safety Valve Leaks	●				●				●	●			●		●									
Safety Valve Set Too Low														●								●		
Speed Demands Exceed Rating																	●							
Speed Lower Than Rating									●	●														
Speed Too High	●	●				●					●				●			●						
Springs Broken																								●
System Demand Exceeds Rating	●				●				●	●			●		●		●							
System Leakage Excessive	●				●				●	●			●		●		●						●	
Tank Ringing Noise					●																			
Unloader Running Time Too Long (1)																●								
Unloader or Control Defective	●	●	●	●	●	●			●	●	●	●	●	●	●		●		●	●	●	●	●	●

Common failures modes of reciprocating compressors

THE CAUSES	THE PROBLEM																							
	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Unloader Parts Worn or Dirty				●																				
Unloader Setting Incorrect	●	●	●		●	●			●	●		●	●	●	●		●		●	●	●	●	●	
V-Belt or Other Misalignment					●	●					●													
Valves Dirty	●	●				●						●	●											●
Valves Incorrectly Located	●	●			●	●			●	●		H ●	L ●	H ●	L ●		●		H ●	H ●				
Valves Not Seated in Cylinder	●	●			●	●			●	●		H ●	L ●	H ●	L ●		●		H ●	H ●				
Valves Worn or Broken	●	●			●	●			●	●		H ●	L ●	H ●	L ●		H ●	H ●	H ●	H ●				
Ventilation Poor	●	●				●									●									
Voltage Abnormally Low			●												●									
Water Inlet Temperature Too High	●	●				●			●			●						●						
Water Jacket or Cooler Dirty	●	●																						

Common failures modes of reciprocating compressors

	THE PROBLEM																							
THE CAUSES	Air Discharge Temperature Above Normal	Carbonaceous Deposits Abnormal	Compressor Fails to Start	Compressor Fails to Unload	Compressor Noisy or Knocks	Compressor Parts Overheat	Crankcase Oil Pressure Low	Crankcase Water Accumulation	Delivery Less Than Rated Capacity	Discharge Pressure Below Normal	Excessive Compressor Vibration	Interceder Pressure Above Normal	Interceder Pressure Below Normal	Intercooler Safety Valve Pops	Motor Over-Heating	Oil Pumping Excessive (Single-Acting Compressor)	Operating Cycle Abnormality Long	Outlet Water Temperature above Normal	Piston Ring, Piston, Cylinder Wear Excessive	Piston Rod or Packing Wear Excessive	Receiver Pressure Above Normal	Receiver Safety Valve Pops	Starts Too Often	Valve Wear and Breakage Normal
Water Jackets or Intercooler Dirty						●						●						●						
Water Quantity Insufficient	●					●			●			●						●						
Wring Incorrect			●																					
Worn Valve on Good Seat																								●
Wrong Oil type		●																	●	●				
(1) Use Automatic Start/Stop Control																								
(2) Use Constant Speed Control																								
(3) Change to Non-Detergent Oil																								
H (in High Pressure Cylinder)																								
L (in Low Pressure Cylinder)																								

Common failures modes of mixers and agitators

	THE PROBLEM						
THE CAUSES	Surface Vortex Visible	Incomplete Mixing of Product	Excessive Vibration	Excessive Wear	Motor Overheats	Excessive Power Demand	Excessive Bearing Failures
Abrasives in Product				●			
Mixer/Agitator Setting Too Close to Side or Corner		●	●	●		●	●
Mixer/Agitator Setting Too High	●	●					
Mixer/Agitator Setting Too Low		●		●			
Mixer/Agitator Shaft Too Long							●
Product Temperature Too Low		●			●	●	
Rotating Element Imbalanced or Damaged		●	●		●	●	●
Speed Too High	●		●	●			
Speed Too Low		●					
Viscosity/Specific Gravity Too High		●			●	●	
Wrong Direction of Rotation		●			●		●

Common failures modes of baghouses

	THE PROBLEM										
THE CAUSES	Continuous Release of Dust-Laden Air	Intermittent Release of Dust-Laden Air	Loss of Plant Air Pressure	Blow-Down Ineffective	Insufficient Capacity	Insufficient Differential Pressure	Fan/Blower Motor Trips	Fan Has High Vibration	Premature Bag Failures	Differential Pressure Too Low	Chronic Plugging of Bags
Bag Material Incompatible for Application									●		●
Bag Plugged						●	●	●			
Bag Torn or Improperly Installed	●							●	●	●	
Baghouse Undersized					●		●				●
Blow-Down Cycle Interval Too Long						●	●				
Blow-Down Cycle Time Failed or Damaged						●	●				
Blown-Down Nozzles Plugged						●					
Blown-Down Pilot Valve Failed to Open (Solenoid Failure)			●			●					
Dust Load Exceeds Capacity											●
Excessive Demand			●								
Fan/Blower Not Operating Properly					●						
Improper or Inadequate Lubrication								●			

Common failures modes of baghouses

	THE PROBLEM										
THE CAUSES	Continuous Release of Dust-Laden Air	Intermittent Release of Dust-Laden Air	Loss of Plant Air Pressure	Blow-Down Ineffective	Insufficient Capacity	Insufficient Differential Pressure	Fan/Blower Motor Trips	Fan Has High Vibration	Premature Bag Failures	Differential Pressure Too Low	Chronic Plugging of Bags
Leaks in Ductwork or Baghouse	●				●						
Misalignment of Fan and Motor								●			
Moisture Content Too High											●
Not Enough Blow-Down Air (Pressure and Volume)			●	●		●					
Not Enough Dust Layer on Filter Bags	●	●						●		●	
Piping/Valve Leaks			●								
Plate-out (Dust Build-up on Fan's Rotor)								●			
Plenum Cracked or Seal Defective	●		●							●	
Rotor Imbalance								●			
Ruptured Blow-Down Diaphrams			●	●		●					
Suction Ductwork Blocked or Plugged					●						

Common failures modes of cyclonic separators

	THE PROBLEM								
THE CAUSES	Continuous Release of Dust-Laden Air	Intermittent Release of Dust-Laden Air	Cyclone Plugs in Inlet Chamber	Cyclone Plugs in Dust Removal Section	Rotor-Lock Valve Fails to Turn	Excessive Differential Pressure	Differential Pressure Too Low	Rotor-Lock Valve Leaks	Fan Has High vibration
Clearance Set Wrong								●	
Density and Size Distribution of Dust Too High				●	●	●			●
Density and Size Distribution of Dust Too Low	●	●							
Dust Load Exceeds Capacity	●	●			●				●
Excessive Moisture in Incoming Air			●						
Foreign Object Lodged in Valve					●				
Improper Drive-Train Adjustments					●				
Improper Lubrication					●				
Incoming Air Velocity Too High						●			
Incoming Air Velocity Too Low	●	●	●				●		
Internal Wear or Damage								●	
Large Contaminates in Incoming Air Stream			●		●				
Prime Mover (Fan, Blower) Malfunctioning	●	●				●	●		●
Rotor-Lock Valve Turning Too Slow	●	●		●					
Seals Damaged								●	

Common failures modes of process rolls

	THE PROBLEM							
THE CAUSES	Frequent Bearing Failures	Abnormal Roll Face Water	Roll Neck Damage or Failure	Abnormal Product Tracking	Motor Overheats	Excessive Power Demand	High Vibration	Product Quality Poor
Defective or Damaged Roll Bearings								●
Excessive Product Tension	●	●	●	●	●	●		●
Excessive Load					●	●		
Misaligned Roll	●	●	●	●	●	●	●	●
Poor Roll Grinding Practices								●
Product Tension Too Loose								●
Product Tension/Tracking Problem		●		●				●
Roll Face Damage	●		●	●				●
Speed Coincides with Roll's Natural Frequency	●			●			●	●
Speed Coincides with Structural Natural Frequency		●		●			●	●

Common failures modes of gearboxes and gear sets

	THE PROBLEM								
THE CAUSES	Gear Failures	Vibrations in Torsional Power	Insufficient Power Output	Overheated Bearings	Short Bearing Life	Overload on Drive	High Vibration	High Noise Levels	Motor Trips
Bent Shaft				●	●	●	●		
Broken or Loose Bolts or Setscrews				●			●		
Damaged Motor						●	●		●
Eliptical Gears		●	●			●	●		
Exceeds Motor's Brake Horsepower Rating			●			●			
Excessive or Too Little Backlash	●	●							
Excessive Torsional Loading	●	●	●	●	●	●			●
Foreign Object in Gearbox	●						●	●	●
Gear Set Not Suitable for Application	●		●			●	●		
Gears Mounted Backwards on Shafts			●				●	●	

Common failures modes of gearboxes and gear sets

	THE PROBLEM								
THE CAUSES	Gear Failures	Vibrations in Torsional Power	Insufficient Power Output	Overheated Bearings	Short Bearing Life	Overload on Drive	High Vibration	High Noise Levels	Motor Trips
Incorrect Center-to-Center Distance Between Shafts							●	●	
Incorrect Direction of Rotation			●			●	●		
Lack of or Improper Lubrication	●	●		●	●		●	●	●
Misalignment of Gears or Gearbox	●	●		●	●		●	●	
Overload	●		●	●	●	●			
Process Induced Misalignment	●	●		●	●				
Unstable Foundation		●		●			●	●	
Water or Chemicals in Gearbox	●								
Worn Bearings							●	●	
Worn Coupling							●		

Common failures modes of steam traps

	THE PROBLEM							
THE CAUSES	Trap Will Not Discharge	Will Not Shut-off	Continuously Blows Steam	Capacity Suddenly Falls Off	Condensate Will Not Drain	Not Enough Steam Heat	Traps Freeze in Winter	Back Flow in Return Line
Back-Pressure Too High				●				
Boiler Foaming or Priming		●				●		
Boiler Gauge Reads Low	●							
Bypass Open or Leaking	●		●					
Condensate Load Greater Than Design		●						
Condensate Short-Circuits					●			
Defective Thermostatic Elements						●		
Dirt or Scale in Trap			●		●			
Discharge Line Has Long Horizontal Runs							●	
Flashing in Return Main				●				●

Common failures modes of steam traps

	THE PROBLEM							
THE CAUSES	Trap Will Not Discharge	Will Not Shut-off	Continuously Blows Steam	Capacity Suddenly Falls Off	Condensate Will Not Drain	Not Enough Steam Heat	Traps Freeze in Winter	Back Flow in Return Line
High Pressure Traps Discharge into Low-Pressure Return								●
Incorrect Fittings or Connectors				●				●
Internal Parts of Trap Broken or Damaged	●	●	●		●			
Internal Parts of Trap Plugged	●				●			
Kettles or Other Units Increasing Condensate Load		●						
Leaky Steam Coils		●						
No Cooling Leg Ahead of Thermostatic Trap						●		●
Open By-Pass or Vent in Return Line				●				
Pressure Regular Out of Order	●							
Process Load Greater Than Design		●						

Common failures modes of steam traps

	THE PROBLEM							
THE CAUSES	Trap Will Not Discharge	Will Not Shut-off	Continuously Blows Steam	Capacity Suddenly Falls Off	Condensate Will Not Drain	Not Enough Steam Heat	Traps Freeze in Winter	Back Flow in Return Line
Plugged Return Lines				●				
Plugged Strainer, Valve, or Fitting Ahead or Trap	●							
Scored or Out-of-Round Valve Seat in Trap						●		
Steam Pressure Too High	●							
System Is Air-Bound					●			
Trap and Piping Not Insulated							●	
Trap Below Return Main				●				●
Trap Blowing Steam into Return				●				
Trap Inlet Pressure Too Low				●	●			
Trap Too Small for Load		●						

Common failures modes of inverters

	THE PROBLEM									
THE CAUSES	Main Circuit Undervoltage	Control Circuit Undervoltage	Momentary Power Loss	Overcurrent	Ground Fault	Overvoltage	Load Short-Circuit	Heat-Sink Overheat	Motor/Invert Overload	Frequent Speed Deviations
Deaccel Time Too Short				●						●
Acceleration Rate Too High									●	●
Ambient Temperature Too High								●		
Control Power Source Too Low			●							
Cooling Fan Failure or Improper Operation								●		
Deceleration Time Too Short						●				●
Excessive Braking Required						●				
Improper or Damaged Power Supply Wiring	●	●								

Common failures modes of inverters

	THE PROBLEM									
THE CAUSES	Main Circuit Undervoltage	Control Circuit Undervoltage	Momentary Power Loss	Overcurrent	Ground Fault	Overvoltage	Load Short-Circuit	Heat-Sink Overheat	Motor/Invert Overload	Frequent Speed Deviations
Improper or Damaged Wiring in Inverter-Motor					●					
Incorrect Line Voltage	●	●				●				
Main Circuit DC Voltage Too Low			●							
Motor Coil Resistance Too Low				●			●			
Motor Insulation Damage				●	●					
Pre-Charge Contactor Open			●							
Process Load Exceeds Motor Rating									●	●
Process Load Variations Exceed System Capabilities										●

Common failures modes of control valves

		THE PROBLEM						
	THE CAUSES	Valve Fails to Open	Valve Fails to Close	Leakage through Valve	Leakage Around Stem	Excessive Pressure Drop	Opens/Close Too Fast	Open/Closes Too Slow
Manually Actuated	Dirt/Debris Trapped in Valve Seat		●	●				
	Excessive Wear		●	●				
	Galling	●	●					
	Line Pressure Too High	●	●	●	●	●		
	Mechanical Damage	●	●					
	Not Packed Properly				●			
	Packed Box Too Loose				●			
	Packing Too Tight	●	●					
	Threads/Lever Damaged	●	●					
	Valve Stem Bound	●	●					
	Valve Undersized					●		●

Common failures modes of control valves

		THE PROBLEM						
	THE CAUSES	Valve Fails to Open	Valve Fails to Close	Leakage though Valve	Leakage Around Stem	Excessive Pressure Drop	Opens/Close Too Fast	Open/Close Too Slow
Point Actuated	Dirt/Debris Trapped in Valve Seat	●	●	●				
	Galling	●	●					
	Mechanical Damage (Seal, Seat)	●	●	●				
	Point Port Blocked/Plugged	●	●	●				
	Pilot Pressure Too High		●				●	
	Pilot Pressure Too Low	●		●				●
Solenoid Actuated	Corrosion	●	●	●				
	Dirt/Debris Trapped in Valve Seat	●	●	●				
	Galling	●	●					
	Line Pressure Too High	●	●	●	●			●
	Mechanical Damage	●	●	●				
	Solenoid Failure	●	●					
	Solenoid Wiring Defective	●	●					
	Wrong Type of Valve (N-O, N-C)	●	●					

Common failures modes of packing and mechanical seals

			THE PROBLEM							
		THE CAUSES	Excessive Leakage	Continuous Stream of Liquid	No Leakage	Shaft Hard to Turn	Shaft Damage Under Packing	Frequent Replacement Required	Bellows Spring Failure	Seal Face Failure
Packed Box	Nonrotating	Cut Ends of Packing Not Staggered	●	●				●		
		Line Pressure Too High	●							
		Not Packed Properly				●	●	●		
		Packed Box Too Loose	●	●						
		Packing Gland Too Loose	●	●						
		Packing Gland Too Tight	●	●		●	●	●		
	Rotating	Cut End of Packing Not Staggered		●						
		Line Pressure Too High	●							
		Mechanical Damage (Seals, Seat)	●	●	●			●		
		Noncompatible Packing	●	●			●			
		Packing Gland Too Loose	●							
		Packing Gland Too Tight			●		●	●		

Common failures modes of packing and mechanical seals

			THE PROBLEM							
	THE CAUSES		Excessive Leakage	Continuous Stream of Liquid	No Leakage	Shaft Hard to Turn	Shaft Damage Under Packing	Frequent Replacement Required	Bellows Spring Failure	Seal Face Failure
Mechanical Seal	Internal Flush	Flush Flow/Pressure Too Low							●	●
		Flush Pressure Too High	●	●					●	●
		Improperly Installed	●						●	●
		Induced Misalignment	●							
		Internal Flush Line Plugged							●	●
		Line Pressure Too High							●	●
		Physical Shaft Misalignment	●							
		Seal Not Compatible	●							

Common failures modes of packing and mechanical seals

			THE PROBLEM							
		THE CAUSES	Excessive Leakage	Continuous Stream of Liquid	No Leakage	Shaft Hard to Turn	Shaft Damage Under Packing	Frequent Replacement Required	Bellows Spring Failure	Seal Face Failure
Mechanical Seal	External Flush	Contamination in Flush Liquid	●							●
		External Flush Line Plugged							●	●
		Flush Flow/Pressure Too Low							●	●
		Flush Pressure Too High	●	●					●	●
		Improperly Installed	●							●
		Induced Misalignment	●						●	●
		Line Pressure Too High							●	●
		Physical Shaft Misalignment	●						●	●
		Seal Not Compatible with Application	●							●

Four Phases to Zero Failure of Static Equipment (Example)

Phase / Equipment	Phase 1
	Establish Basic Conditions
Columns, tanks, piping, heat exchangers, furnaces, valves, measuring instruments, etc.	[A] Exteriors (parts in contact with the outside environment) a. Remove corrosion products, and keep surfaces dry. b. Replace damaged, discolored thermal insulation ; investigate reasons for deterioration. c. Check for corrosion inside insulation ; dry affected parts. d. Investigate/repair leaks and seepage. e. Check for damaged piping supports. f. Investigate causes of vibration and shock (water hammering, etc.) g. Remove corrosion products from beams, supports and other structures, repair where necessary.. [B] Interiors (parts in contact with process fluids, steam, water, etc.) a. Investigate/repair internal corrosion, deformation, slackness, fallen-off parts . b. Investigate/repair corrosion and cracking of main units.. c. Investigate/remove contamination, scaling, clocks, etc. d. Investigate variations in operating conditions and equipment conditions.

(-Continued)

Phase / Equipment	Phase 2 Lengthen Equipment Life
Columns, tanks, piping, heat exchangers, furnaces, valves, measuring instruments, etc.	**[A] Exteriors (parts in contact with the outside environment)** a. Check exteriors regularly. b. Rustproof and paint exteriors periodically. c. Periodically renew insulation and supports.. **[B] Interiors (parts in contact with process fluids, steam, water, etc.)** a. Perform periodic overhaul inspection. b. Periodically replace internal parts. c. Periodically repair and renew deteriorated parts. d. Descale periodically. e. Plan and implement medium-term renovation plans for piping, tanks, heat exchangers, etc. f. Correct weakness in strength. g. Identify relationships between rate of equipment deterioration and process conditions such as raw material properties and operating conditions, and select parts conformable to operating conditions.

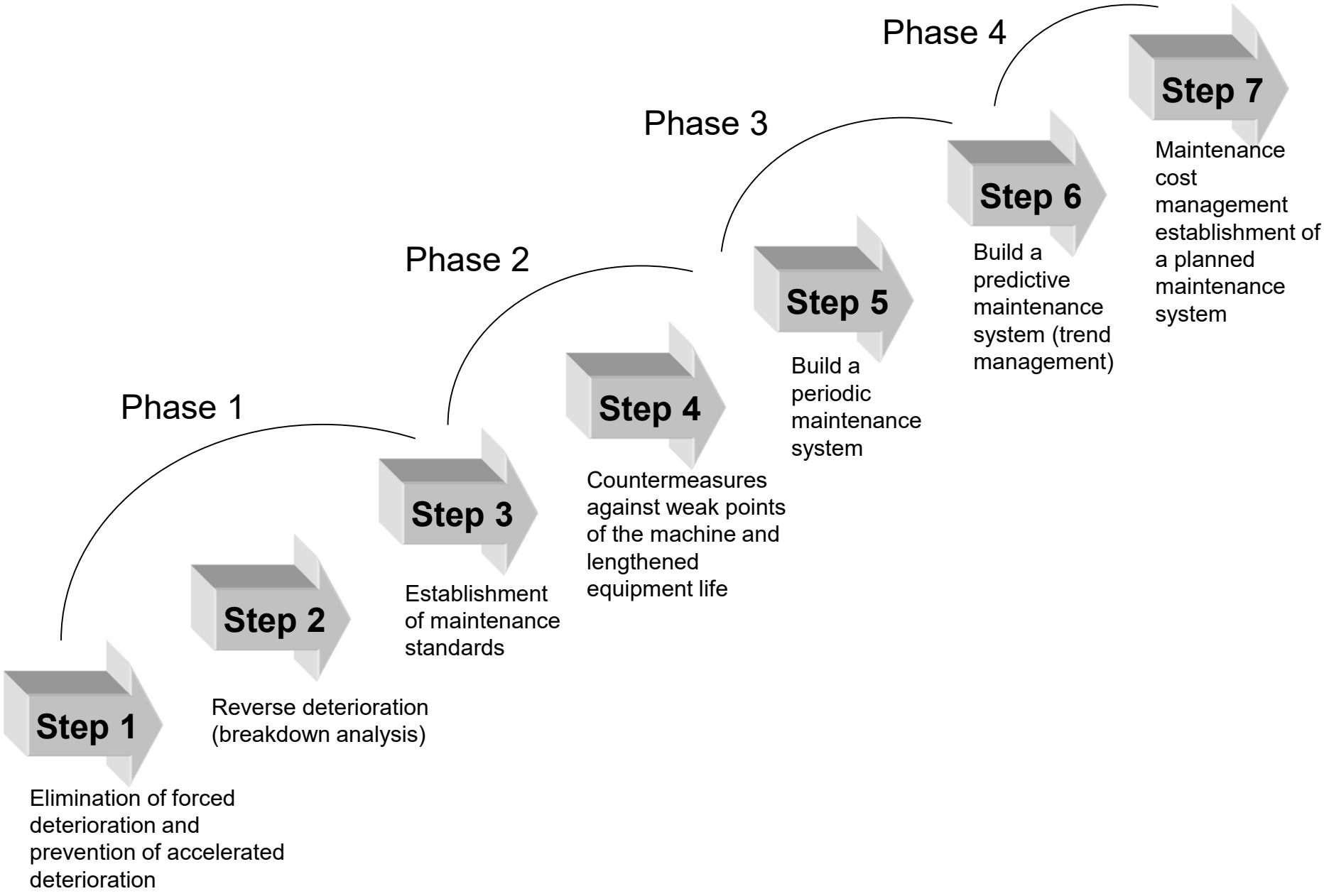
(-Continued)

Phase / Equipment	Phase 3 Periodically Restore Deterioration
Columns, tanks, piping, heat exchangers, furnaces, valves, measuring instruments, etc.	**[A] Exteriors (parts in contact with the outside environment)** a. Repair and prevent local corrosion. b. Repair and prevent rainwater ingress.. c. Repair and prevent leaks and seepage. d. Alleviate or prevent vibration and shock. e. Improve beans, supports, and other structures. **[B] Interiors (parts in contact with process fluids, steam, water, etc.)** a. Relieve stress concentrations (static loads, dynamic loads, thermal stress). b. Relieve and improve thermal fatigue. c. Correct and prevent local corrosion. d. Correct and prevent leaks and seepage. e. Introduce improvements to prevent contamination and scaling. f. Introduce improvements to prevent blocks. g. Introduce improved methods of adding process-problem prevention agents. (such as polymerization inhibitors). **[C] Common items** a. Investigate and adopt novel anti-corrosion and anti-erosion coatings. b. Investigate and adopt novel corrosion-resistant materials. c. Improve gasket coatings. d. Introduce improved repair techniques such as thermal spraying.

(-Continued)

Phase / Equipment	Phase 4 Predict and Extend Equipment Lifetimes
Columns, tanks, piping, heat exchangers, furnaces, valves, measuring instruments, etc.	**[A] Predict materials deterioration and extend lifetimes** a. Perform non-destructive materials tests. b. Perform destructive tests and microstructure tests on samples. c. Investigate and analyze deterioration mechanisms by destructive and non-destructive testing. d. Develop and introduce internal corrosion monitoring devices and technology for equipment such as piping. e. Develop novel materials and technology to extend equipment life. f. Investigate repair and fabrication techniques such as welding and thermal spraying. g. Review and improve operating conditions. **[B] Interiors (parts in contact with process fluids, steam, water, etc.)** a. Lengthen descaling intervals by monitoring contamination and adhesion and employing initial in-line cleaning. b. Extend continuous operation by analyzing changes in raw materials, operating conditions and equipment conditions, and relating these to the occurrence of contamination and adhesion.

Seven Steps of Establishing a Professional Maintenance System



Professional Maintenance of Equipment

	Phase 1 Stabilize mean time between failures (MTBF)	Phase 2 Lengthen equipment's life	Phase 3 Periodically restore deterioration	Phase 4 Predict equipment's life
Periodic Maintenance	**Step 1** Elimination of forced deterioration and prevention of accelerated deterioration **Step 2** Reverse deterioration (breakdown analysis) **Step 3** Establishment of a maintenance standard		**Step 5** Build a periodic maintenance. and efficient inspection.	
Corrective maintenance		**Step 4** Countermeasures against weak points of the machine and lengthened equipment life		
Predictive Mmaintenance		**Step 6** Machine overall diagnosis		**Step 6** Build a predictive maintenance (trend management)
Quality maintenance				
Establishment of a planned maintenance system	**Step 7** Evaluate the planned maintenance system and establish a computerized maintenance system.			

Concept of Step-by-Step Activities

Step	Activities
Step 1 **Elimination of forced deterioration and prevention of accelerated deterioration**	1.Prepare (or update) equipment ledgers. 2.Evaluate equipment : establish evaluation criteria, prioritize equipment and select PM equipment and components. 3. Define failure ranks. 4. Understand situation: measure number, frequency and severity of failures and minor stoppages, MTBF's, maintenance costs, breakdown maintenance rates, etc. 5. Set maintenance goals (indicators, methods of measuring results). 6. Restore deterioration, maintain basic conditions and eliminate environments causing forced deterioration (support AM activities) .

Concept of Step-by-Step Activities (2)

Step	Activities
Step 2 **Reverse deterioration** **(breakdown analysis)**	1. Take measures to prevent identical or similar major failures from occurring. 2. Introduce improvements to reduce process failures.

Concept of Step-by-Step Activities (3)

Step	Activities
Step 3 **Establishment of maintenance standards**	1. Prepare for periodic maintenance (Control standby equipment, spare parts, measuring instruments, lubricants, drawings and technical data, etc.) 2. Prepare time-based (periodic) maintenance system flow diagram. 3. Select equipment, components to be maintained and members and formulate a maintenance plan. 4. Prepare or update standards (material standards, work standards, inspection standards, acceptance standards, etc.) 5. Improve shutdown maintenance efficiency and strengthen control of subcontracted work.

Concept of Step-by-Step Activities (4)

Step	Activities
Step 4 **Countermeasures against weak points of the machine and length-ended equipment life**	1. Conduct focused improvement activities to correct weaknesses and extend life times.

Concept of Step-by-Step Activities (5)

Step	Activities
Step 5 **Build a periodic maintenance system**	1. Build failure data management system. 2. Build equipment maintenance management system. 3. Prepare periodic maintenance calendar. 4. Build systems for controlling standby units and spares.

Concept of Step-by-Step Activities (5)

Step	Activities
Step 6 **Build a predictive maintenance system** **(trend management)**	1. Introduce equipment diagnostics (train diagnosticians, and purchase diagnostic equipment, etc.) 2. Prepare predictive maintenance system flow diagram . 3. Select equipment and components for predictive maintenance, and extend gradually. 4. Develop diagnostic equipment and technology.

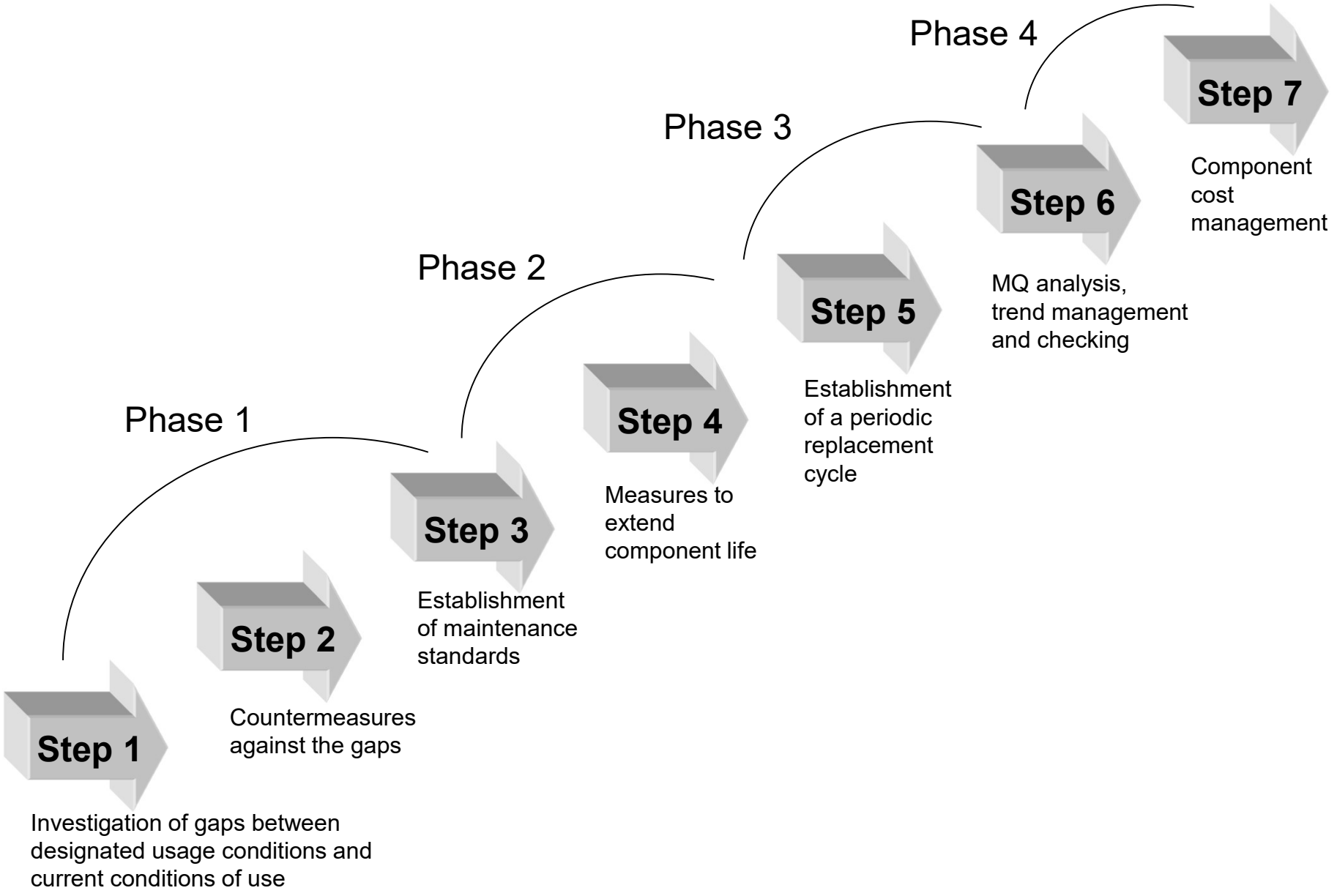
Concept of Step-by-Step Activities (6)

Step	Activities
Step 7 **Maintenance cost management** **Establishment of a planned maintenance system**	1. Build an equipment budget management system. 2. Evaluate cost savings : decrease in maintenance expenditures and improvement in distribution of maintenance costs. 3. Evaluate the planned maintenance system. 4. Evaluate reliability improvement ; number of failures and minor stoppages, MTBF, failure frequency, etc. 5. Evaluate maintainability improvement : Periodic maintenance ratio, predictive maintenance ratio, MTTR, etc.

Seven Steps of Establishing a Professional Maintenance System (Human side)

	Phase	Step	Title	Objectives
7 Steps of Planned Maintenance	1 Stabilize MTBF	1	Elimination of forced deterioration and prevention of accelerated deterioration	・Let the operators learn the aims, structure and function of the equipment and recognize the importance of keeping of basic conditions of use. ・Make them realize that letting the apparent deterioration to take place is the proof of their inability as maintenance men.
		2	Reverse deterioration (breakdown analysis)	・Apply what was learned in 1 to other machines and overall improvement methods. ・Educate them to carry out autonomous maintenance by giving them knowledge on lubrication and fastening, and by raising their skills.
		3	Establishment of maintenance standards	・Make out the maintenance standards and identify their roles by themselves, review the problems and learn the improvement steps.
	2 Lengthen equipment life span	4	Countermeasures against weak points of the machine and lengthened equipment life	・Change the way to observe phenomena and learn the steps of improvement through their own analysis. ・Search for the true causes by utilizing MTBF analysis.
	3 Periodically restore deterioration	5	Build a periodic maintenance system	・Change the way of observing things and learn the improvement of operation procedures, tools and cost. ・Learn about the accuracy and efficiency of visual control. ・Learn the usage of indicators.
	4 Predict breakdowns	6	Build a predictive maintenance system (trend management)	・Learn the method and application of MQ analysis and reliability analysis. ・Learn the quality characteristics determined by the equipment and their correlation. ・Learn machine diagnosis techniques.
		7	Maintenance cost management. Establishment of a planned maintenance system	・Learn to predict component's lifetime through data analysis.

Seven Steps of Establishing Professional Maintenance (component level)



Professional Maintenance of Components

	Phase 1 Stabilize mean time between failures (MTBF)	Phase 2 Lengthen component's life	Phase 3 Periodically restore deterioration	Phase 4 Predict component's life
Periodic maintenance	**Step 1** Investigation of gaps between designated usage conditions and current conditions of use **Step 2** Countermeasures against the gaps **Step 3** Establishment of maintenance standards		**Step 5** Establishment of a periodic replacement cycle.	
Corrective maintenance		**Step 4** Measures to extend component life.		
Predictive maintenance				**Step 6** Trend management and checking
Quality maintenance				MQ analysis
Establishment of a planned maintenance system	**Step 7** Component cost management			

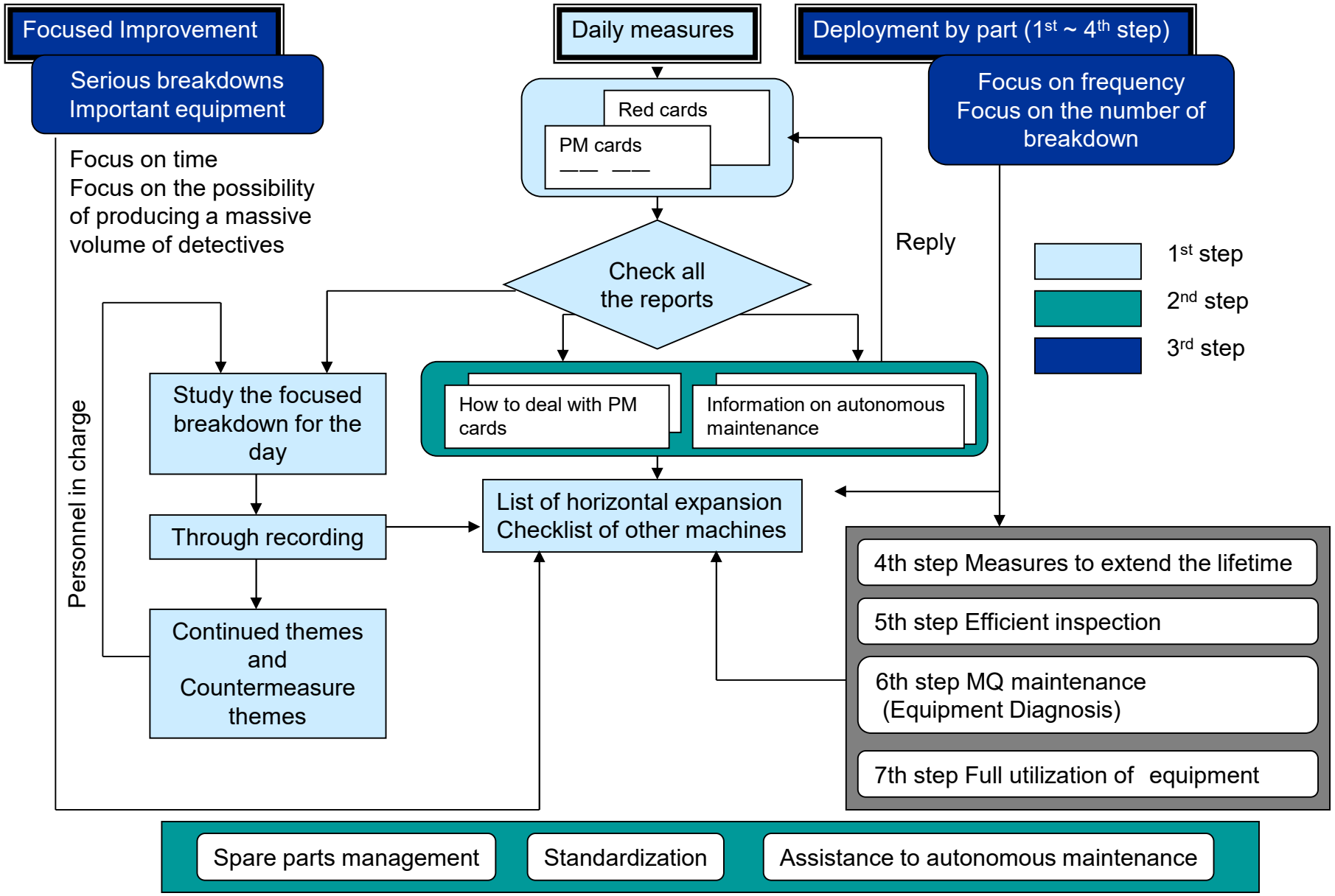
Seven Steps of Establishing Professional Maintenance (component level)

	Phase	Step	Title	Objectives
7 Steps of Professional Maintenance (component level)	1 Stabilize mean time between failures (MTBF)	1	Investigation of gaps between designated usage conditions and current conditions of use	・Selection of important components. ・Restoration of the apparently deteriorated parts. ・Clarification of designated usage conditions. ・Investigation of gaps between designated usage conditions and current conditions of use.
		2	Countermeasures against the gaps	・Elimination of the gaps and improvement of the reliability of the equipment.
		3	Establishment of maintenance standards	・Setting tentative maintenance standards, especially for cleaning , lubricating and retightening. ・Clarification of roles of maintenance for production and maintenance.
	2 Lengthen component's life	4	Measures to extend component life	・Definition and improvement of conditions of use. ・Extension of the lifetime by corrective maintenance. ・Elimination of chance failures caused by human errors and repair errors.
	3 Periodically restore deterioration	5	Establishment of a periodic replacement cycle and improvement of inspection efficiency	・Setting maintenance standards and improvement of maintanability, operationability, and safety. ・Investigation of abnormal symptoms indicating deterioration. ・Execution of countermeasures against weak points in carrying out inspection.
	4 Predict component's life	6	MQ analysis, trend management and checking	・Establishment of CBM and Quality maintenance by MQ analysis. ・Clarifications of the relationships between the equipment and the product quality, and maintenance of product quality by PM.
		7	Component cost management	・Determination of the limit point of the component. ・Technical analysis of catastrophic breakdowns. ・Utilization of equipment diagnosis techniques.

No.	Quality component	Phenomenon	Preventive measure	Method of checking
	(Direct-type)			
1	Rollers	scratches, rust, wear, adhesion of foreign matter, soiling	clean	by touch
2	Spools	scratches, soiling, deformation, off-centering	handle with care	measure using gauges
3	Bearings	play, wear	lubricate	by stethoscope
4	Locators	displacement, slackness	tighten	matchmarks
5	Dies and molds	wear, corrosion, inaccuracy	accuracy control	dimensional measurement
6	Heaters	cutout	clean	measure current
7	Thermocouples	disconnection, removal	fix in position	visual check
8	Hoses and pipes	blockage, cracking	clean	measure flow rate
9	Couplings	play	tighten	check dimensions
10	Belts	slackness, wear	clean	measure slack
11	Chains	slackness, stretching	clean	measure tension
12	Brake shoes	wear	regular inspection	check dimensions
13	Chutes	blockage	regular inspection	visual check
14	Filters, strainers	blockage	regular inspection	pressure measurement
15	Presses and other machines	misalignment	accuracy control	measurement
16	Traversers	inaccurate movement	accuracy control	measurement
	(Indirect type) → cutting oil, coolant, air, and other fluids			
1	Dirt and foreign matter	blockage, surface damage	anti-source measures	check for dirty filters
2	Temperature	dispersion, temperature drop between inlet and outlet	regular inspection	measurement
3	Flow rate	blockage	regular inspection	visual check
4	Pressure	pumping-system abnormalities	regular inspection	visual check
5	Voltage, current	faulty contacts	regular inspection	visual check
6	Noise	disturbance	install shields	measure
7	Poles, slip rings	wear	regular inspection	measure

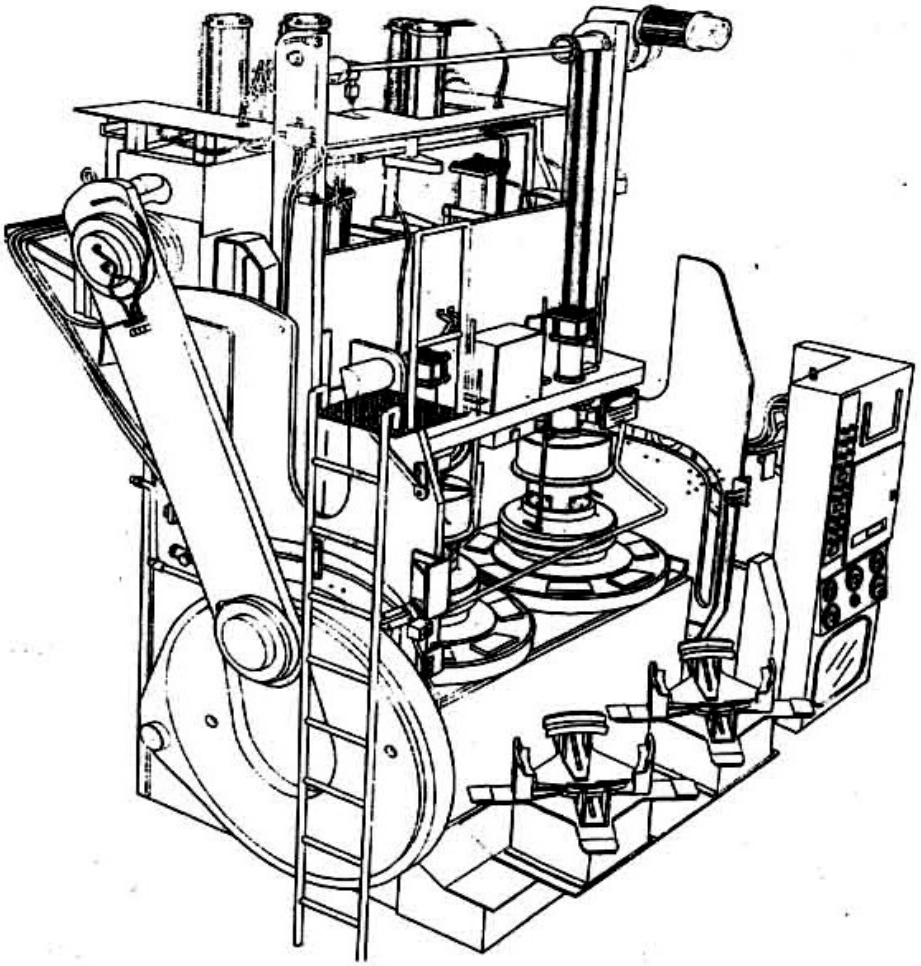
Figure. Direct and Indirect Quality Components

Development of professional maintenance (component level)

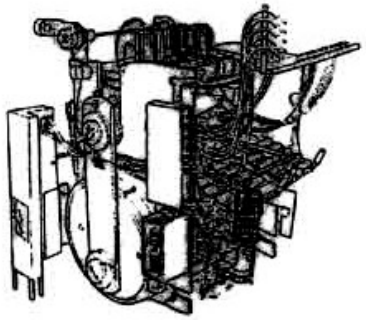


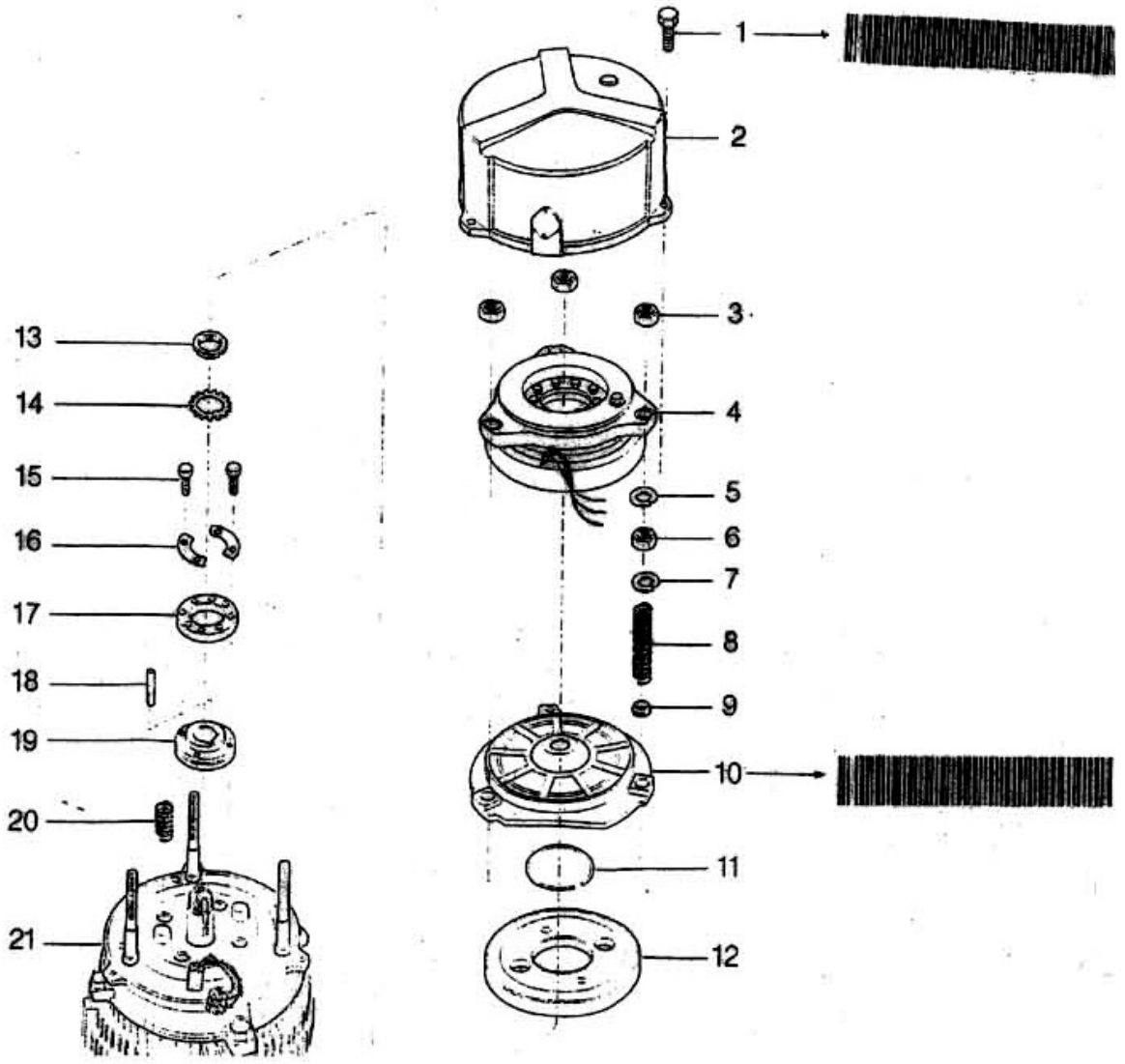
Importance of Making an Equipment Ledger

Equipment Ledger



Section A Component 1

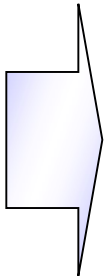




Section a component 1

Part num-ber	Part name	Func-tion	De-fect mode	Influence		Evaluation of breakdown			Over all evaluation
				Sub-sys tem	Sys tem	Occurr ence probabi lity A	The de-gree of influ-ence B	The easi-ness of detec-tion C	A × B × C
1 2 3					○	0.001	5	2	0.001

Classification of part	Type of maintenance needed	Cycle of replacement or inspection	Part history of breakdowns and replacement				
			Initial failure	Chance failure	Wear out failure	MTBF and deviation	MTTR and deviation
A	TBM	1/3 mos	0	0	3	1500H/ 100H	1H/ 10M



Maintenance			Spare part			
When	Who	How	Address of the warehouse	Number of pieces left	Replenish-ing method	Supplier
						Tel:

History of component 1

Describe all events which happened to the component 1 in the chronological order.

What are the problems?

NOK

- remove the mould + casting from the box

OK

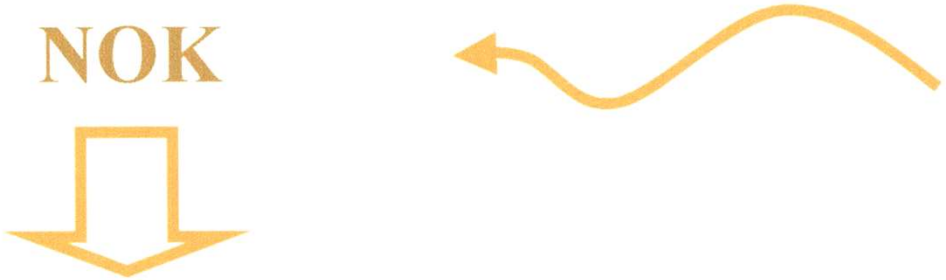
- put the mould + casting in the cooling box

NOK

- deliver clean boxes to the moulding line

2. Importance of the problem

Why is this a problem?



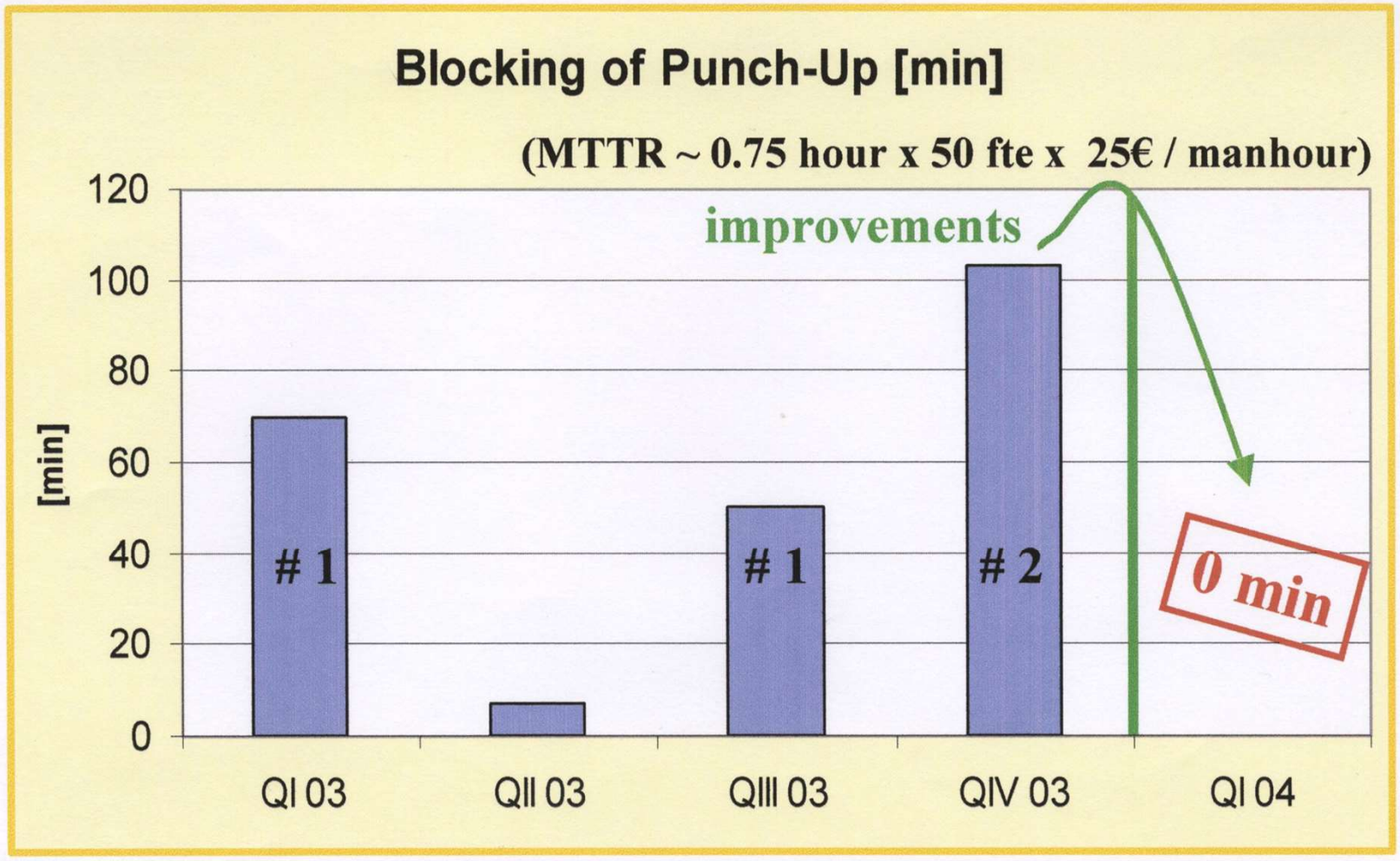
If punch-up is blocked (pieces of casted iron),
the whole moulding line stands still

(MTTR ~ 0,75 hour x 50 fte x 25€ / manhour)

- remove the mould + casting from the box
- put the mould + casting in the cooling box
- deliver clean boxes to the moulding line

PM: PUNCH-UP

3. Results



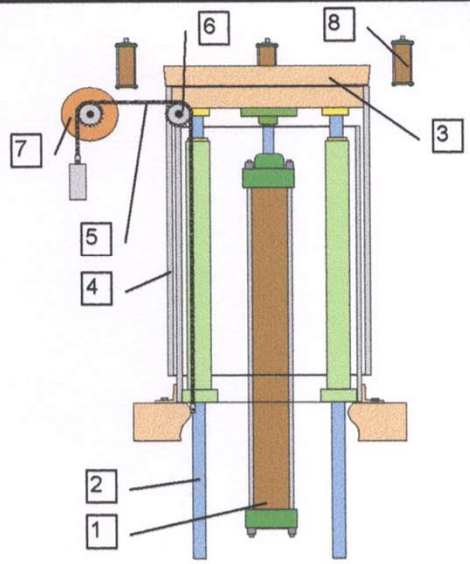
PM: PUNCH-UP

4. Breakdown analysis

EQP.-NR. **TL065**

EQP.-NAAM: **Punch-Up**

* soort onderhoud: TBM (tijdsgebonden onderhoud)
CBM (condietiegebonden onderhoud) PRM(preventief vervangen)
BDM (vervangen bij breuk)



VERTICALE BEWEGING

Ledger

nr	S-Nr.	Omschrijving	Groep (aandrijving, hydraulisch, elektrisch,...)		#	ABC - class.	Soort Onderhoud*		Part-history				
							NU	LATER	# t.g.v. kinder-ziektes	# in bedrijfs-periode	# t.g.v. veroude-ring	MTBF (dagen)	MTTR (man-uren)
1		cilinder	verticale beweging	cilinder	1	A	CBM	CBM	0	1/1/5j	1/1/1j	1j	48h
2	S 18260	geleidingsas	verticale beweging	geleidingsas	2	A	CBM	CBM	0	0	2/2/1j	1j	48h
3		stempel	verticale beweging	stempel	1	A	CBM	CBM	0	0	1/1/5j	5j	48h
4		mantel	verticale beweging	mantel	1	B	CBM	CBM	0	0	1/1/1j	1j	48h
5		ketting	verticale beweging	positieopnemer	1	A	BDM	BDM	0	0	1/1/15j	15j	15min
6	S 18425	kettingwiel	verticale beweging	positieopnemer	2	A	BDM	BDM	0	0	1/1/15j	15j	15min
7		contacten	verticale beweging	positieopnemer	4	A	BDM	BDM	0	0	4/4/15j	15j	1h
8	S0060756	kastenklemcilinder	verticale beweging	kastenklemcilinder	3	B	BDM	BDM	0	0	1/3/4j	12j	1h
9		hydrauliek	verticale beweging	hydrauliek	-	A	BDM	BDM	0	0	1/5j	5j	1h

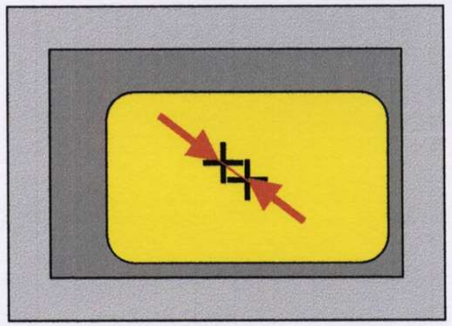
5 WHY

Pieces of casted iron block the punch-up

1. Too much clearance between stamp and frame

Stamp isn't centred in frame

1.1. Positioning stamp isn't correct (wrong assembly)



Centre Punch-Up during next change of stamp

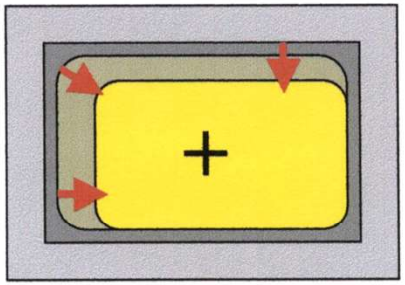
5 WHY

Pieces of casted iron block the punch-up

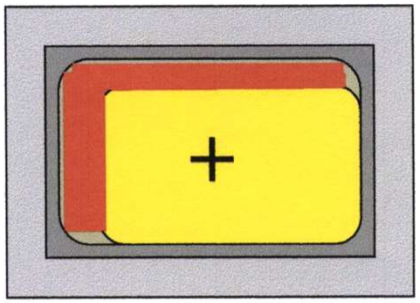
1. Too much clearance between stamp and frame

Stamp isn't centred in frame

1.2. Asymmetrical deterioration of stamp



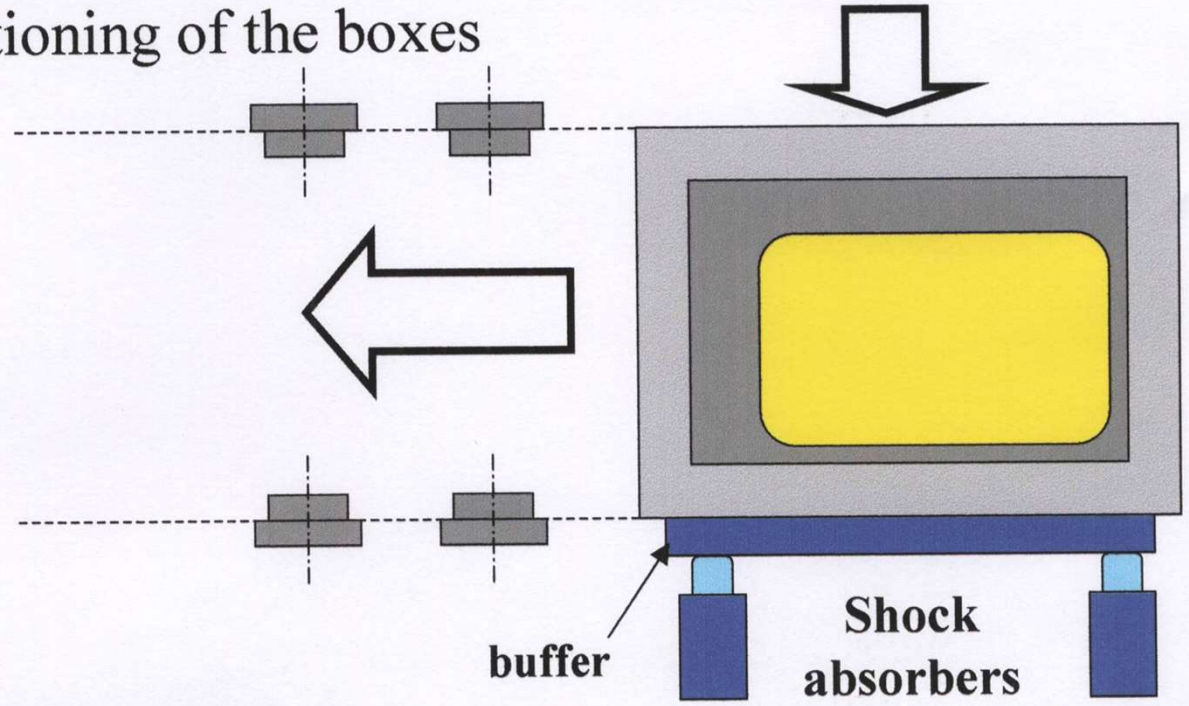
Weld extra material to reduce clearance



5 WHY

Pieces of casted iron block the punch-up

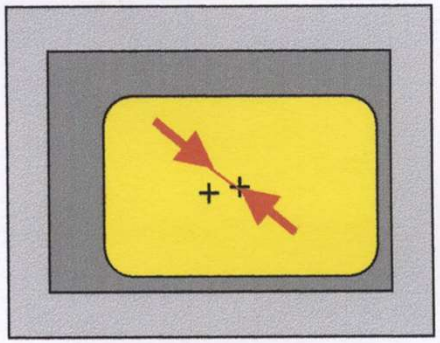
2. Bad positioning of the boxes



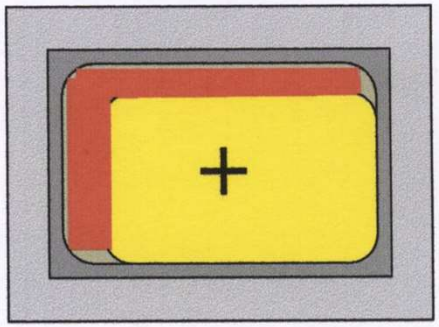
Buffer can't be thinner;
Box must be positioned on the fixed wheels

Pieces of casted iron block the punch-up

- Centre Punch-Up during next change of stamp



- Weld extra material to reduce clearance



- adjust positioning of Punch-Up (~ flexible connection plunjer)

- repair stamp (adjust clearances)

- expand preventive maintenance (check deterioration of the stamp)

2. Importance of the problem

Why is this a problem?

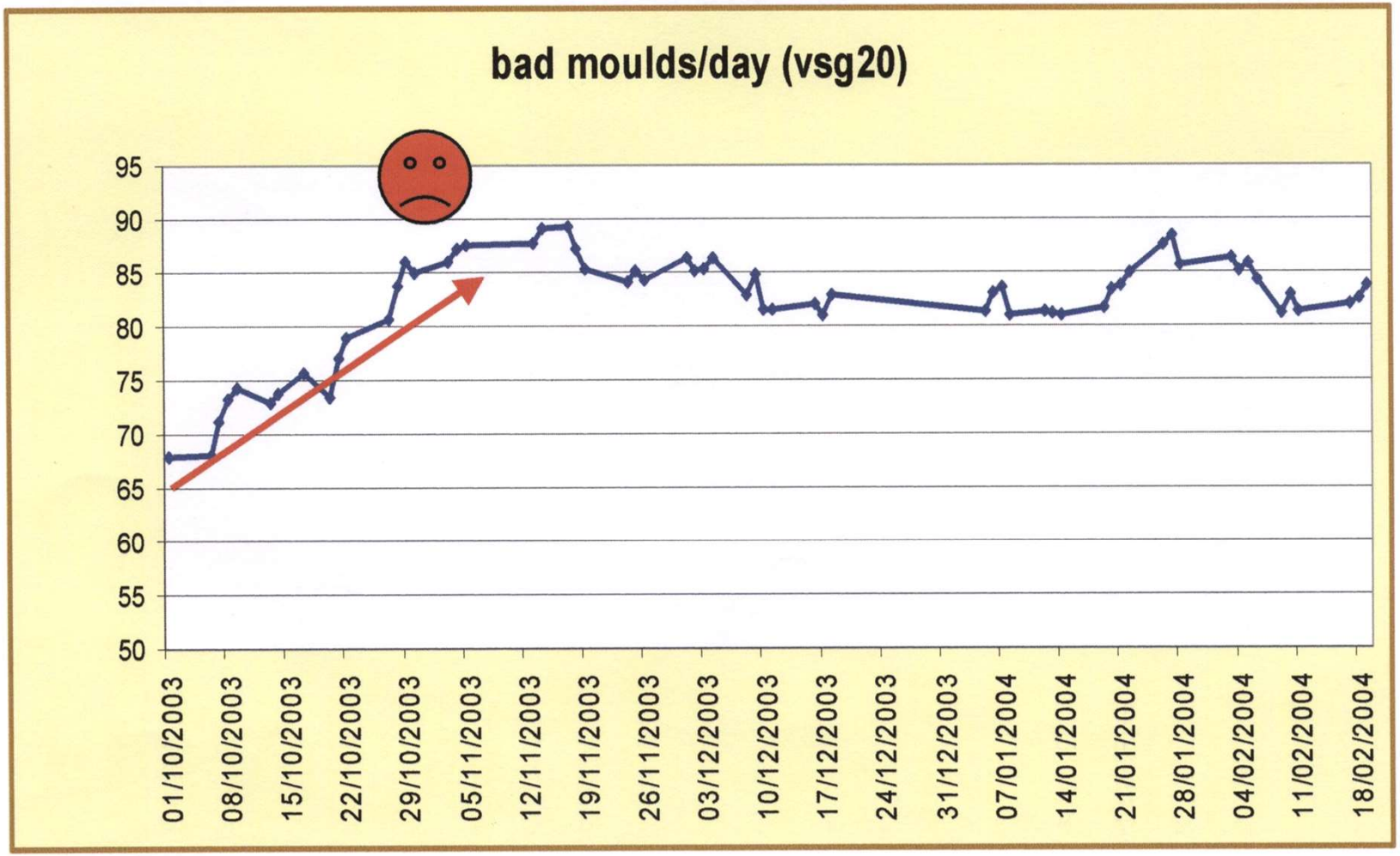
The remaining sand in the box prevents creating a good mould

NOK

- remove the mould + casting from the box
- put the mould + casting in the cooling box
- deliver clean boxes to the moulding line

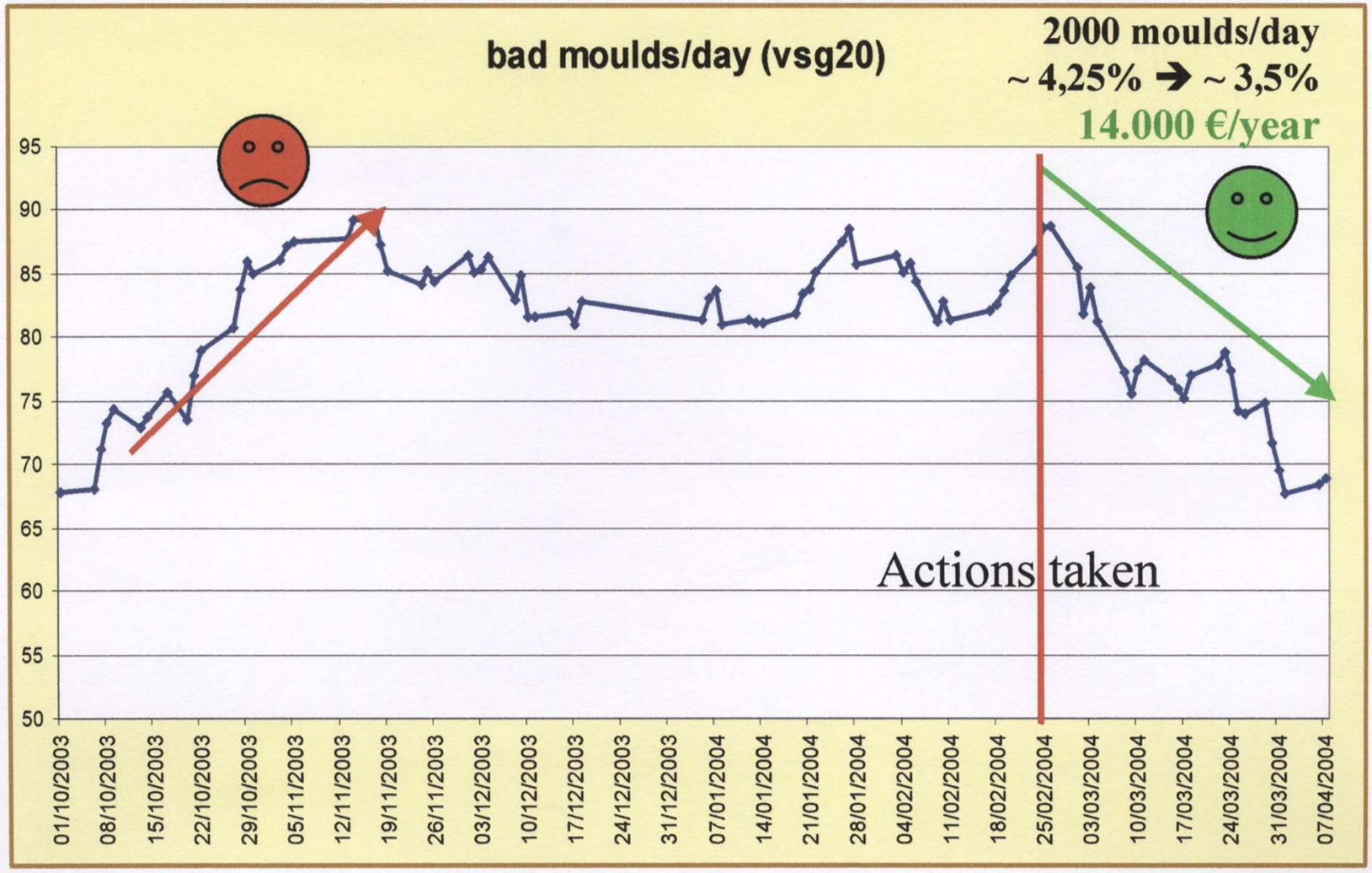
PM: PUNCH-UP

3. Results



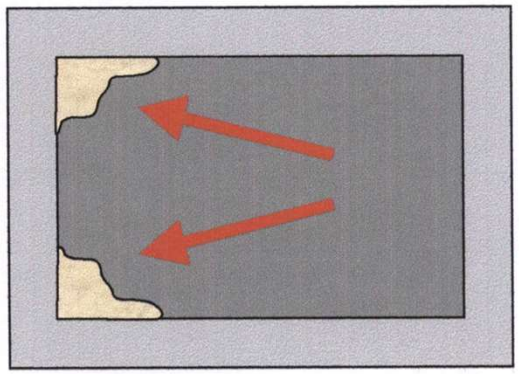
PM: PUNCH-UP

3. Results



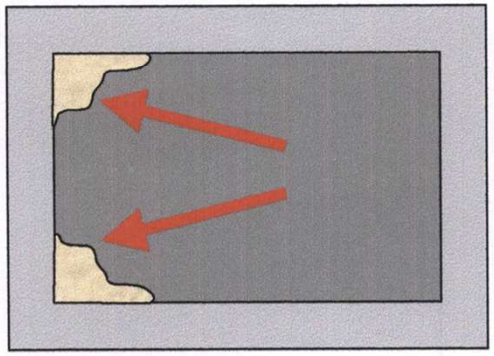
Too much sand remains in the boxes

5 WHY

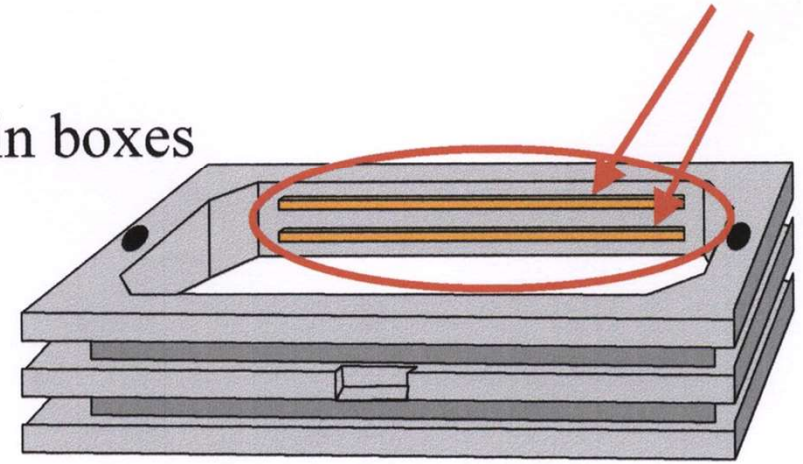


- Inner side of boxes is too rough
- Boxes have been shot blasted (~tuning boxes)
- **Coat all boxes (~ smoothen surface)**

Too much sand remains in the boxes 5 WHY

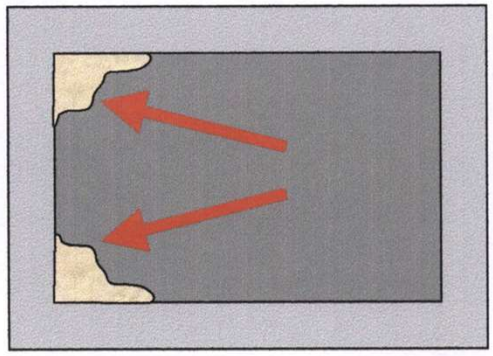


Sand sticks on small rails in boxes



Small rails are necessary to prevent sinking of the mould

Too much sand remains in the boxes **5 WHY**

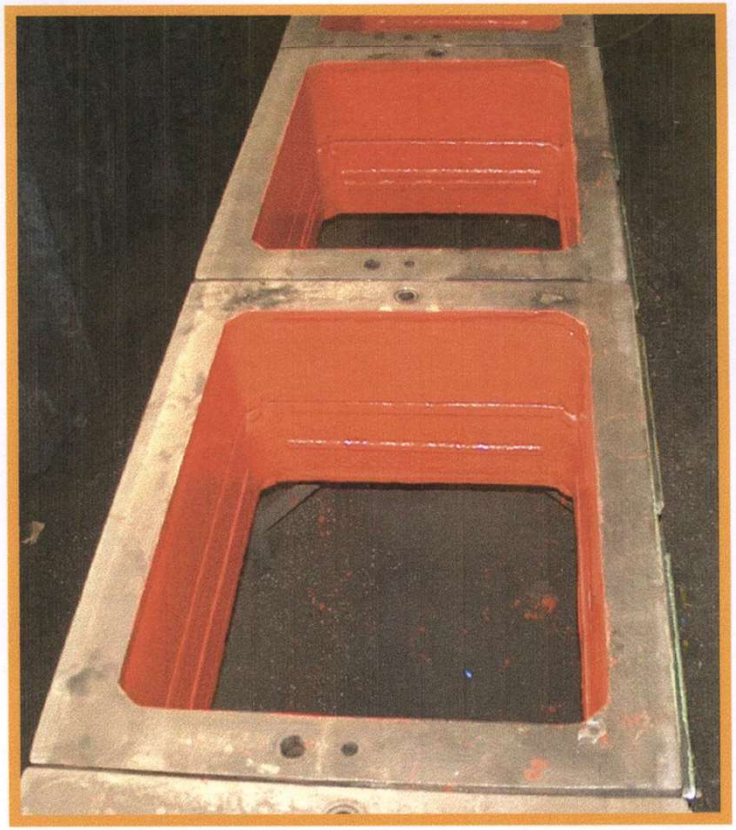


Too much clearance between stamp and frame

(See previous slides)

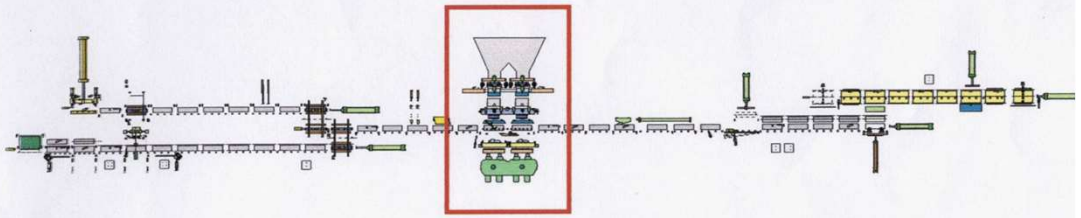
Too much sand remains in the boxes

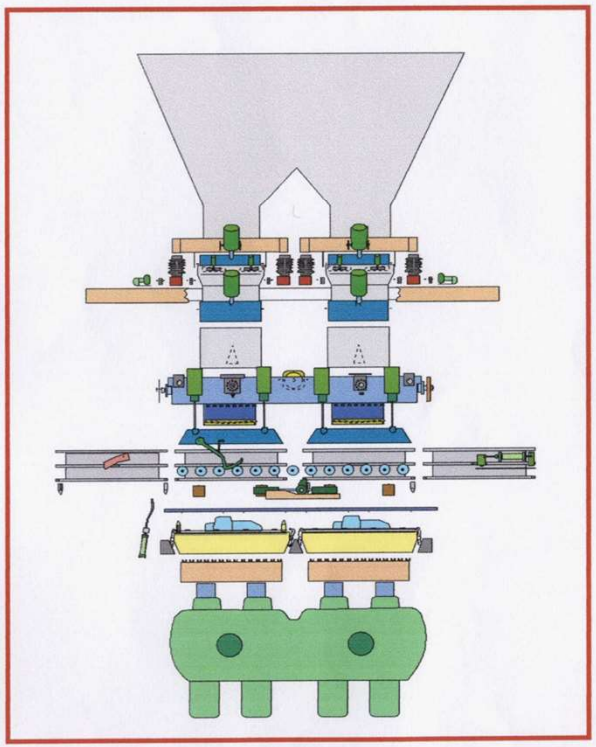
→ **Coat all boxes (~ smoothen surface)**



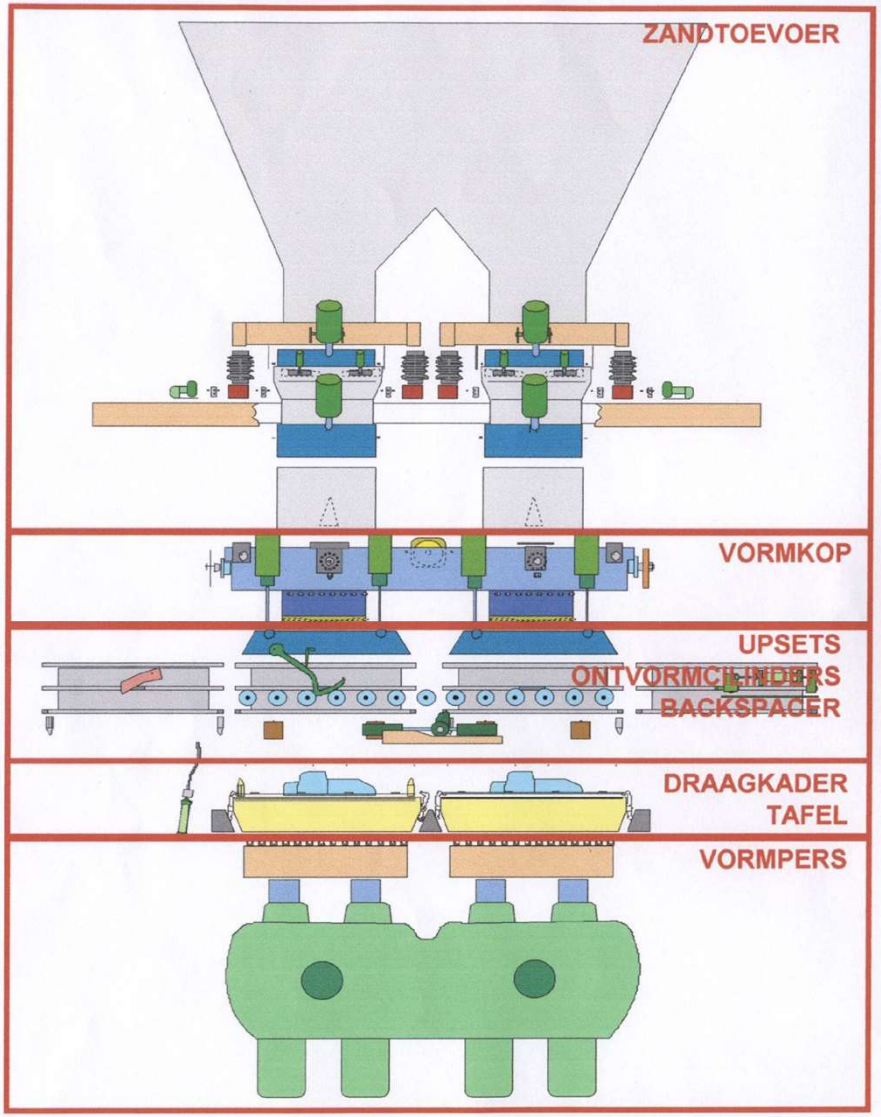
LEDGER VORMMACHINE TACCONE

TL 60





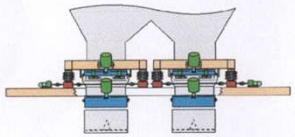
VORMMACHINE



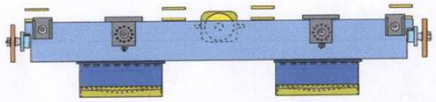
ledger vormmachine

gdbs, vdcr

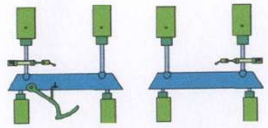
VORMMACHINE



- ZANDTOEVOER
  - DOSEUR
    - aandrijfas
    - aandrijfmotor
    - koppelingen
    - luchtcilinder zandpoorten (onderste)
    - luchtcilinder zandschopjes
    - pneumatiek luchtcilinders zandpoorten
    - pneumatiek luchtcilinders zandschopjes
    - reductoren
    - vibratoren
    - zandpoorten (onderste)
    - zandschopjes
  - SILO
    - blaasstenen
    - luchtcilinder zandpoorten (bovenste)
    - niveaumeter
    - pneumatiek luchtcilinders
    - vibratoren
    - zandpoorten (bovenste)
  - ZANDINLAAT
    - plastiek bekleding
    - verdeelkegel



- DWARSKOP
  - CHASSIS
    - pastilles
    - slijtlatten
  - VORMKOPPEN
    - membraan
    - pneumatiek membraan
  - SCHOKDEMPERS
    - schokdempers
    - hydrauliek schokdempers
    - pneumatiek schokdempers
  - STOOTBLOKKEN
    - lichaam
    - regelvijs
  - LOOPWIELEN
    - assen
    - kogellagers
    - looplatten
    - wielen
  - PERSLUCHTCILINDER
    - luchtcilinder
    - pneumatica

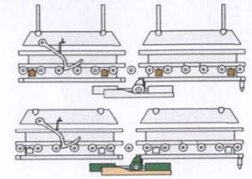


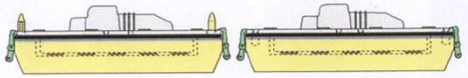
- UPSETS
  - KADER
  - PNEUMATISCHE CILINDERS
    - achterste
    - voorste
    - benaderingsschakelaars
    - pneumatiek
  - KROMME HAAK
  - SPROEIERS LOSSINGSMIDDEL

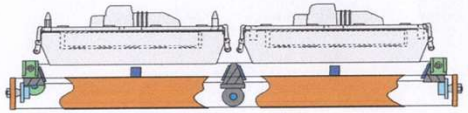
ledger vormmachine

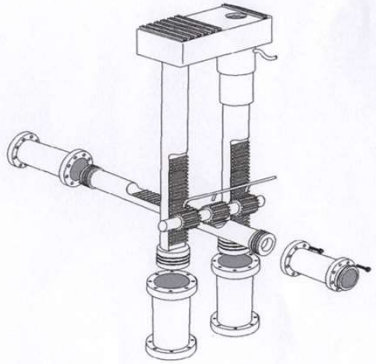
gdbs, vdcr

- ONTVORMCILINDERS
  - CILINDER
  - HYDRAULIEK
- BACKSPACER
  - HAAK
  - CILINDER
  - PNEUMATIEK
  - LOOPLATTEN
- DRAAGKADERS
  - BLOK
  - STEUNPLAATJES
  - KLAMHAKEN
  - PADDESTOELEN
  - PINNEN KASTEN
  - BUSSEN KASTEN
  - BUSSEN MODELPLATEN
- TAFEL
  - CHASSIS
  - LOOPWIELEN
    - wielen
    - kogellagers
    - assen
  - PERSLUCHTCILINDER
  - SCHOKDEMPERS
  - V-BLOKKEN KLAMHAKEN
  - STOOTBLOKKEN
    - lichaam
    - regelvijs
- VORMPERS
  - RAM
    - verticale tandlatten
    - horizontale tandlatten
    - transmissieas
    - zuigers horizontale tandlatten
    - zuigers verticale tandlatten
    - cilinderbuis horizontale zuigers
    - cilinderbuis verticale zuigers
    - hydraulica
    - jupes
    - blok
    - u-profielen
  - CARTER
    - smeerpompen
    - terugvoerpomp
    - aanzuigfilter smeerpomp
    - aanzuigfilter terugvoerpomp
    - terugloopfilter smeerpomp
    - terugloopfilter terugvoerpomp
    - niveaumeters
  - SCHOKDEMPERS
- LOOPWIELEN TRANSFERLIJN









ledger vormmachine

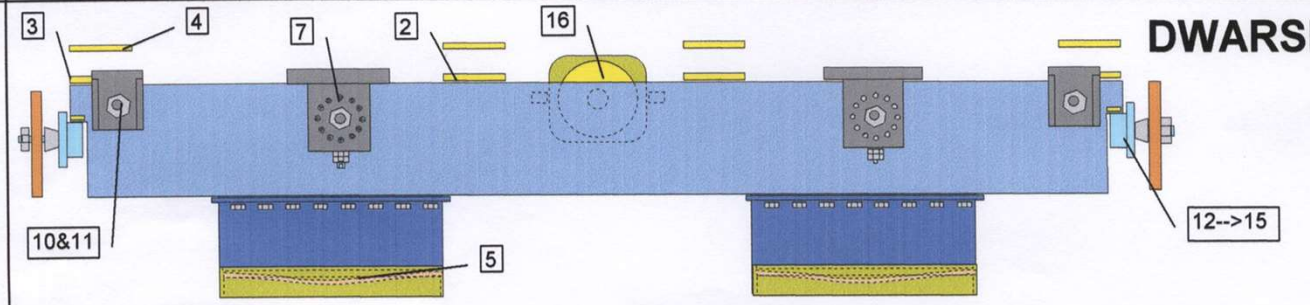
gdbs, vdcr

EQP.-NR. **TL 60** (TL 63)

EQP.-NAAM: **Vormmachine**

* soort onderhoud: TBM (tijdsgebonden onderhoud)
CBM (condietiegebonden onderhoud) PRM(preventief vervangen)
BDM (vervangen bij breuk)

nr	S-Nr.	Omschrijving	Groep (aandrijving, hydraulisch, elektrisch,...)		#	ABC - class.	Soort Onderhoud*		Part-history				
							NU	LATER	# t.g.v. kinder-ziektes	# in bedrijfs-periode	# t.g.v. veroude-ring	MTBF (dagen)	MTTR (man-uren)
15		pneumatiek luchtcilinders zandpoorten	zandtoevoer	silo	-	C	BDM	BDM	0	0	1/j	1j	30min
16		vibratoren	zandtoevoer	silo	4	B	BDM	BDM	0	1/4/1j	2/4/1j	16m	30min
17	S0044408	zandpoorten (bovenste)	zandtoevoer	silo	2	C	PRM	PRM	0	0	2/2/1j	1j	80h
18		plastiek bekleding	zandtoevoer	zandinlaat	2	C	BDM	BDM	0	0	2/2/1j	1j	2h
19	S0046473	verdeelkegel	zandtoevoer	zandinlaat	4	B	CBM	CBM	0	0	1/4/1j	4j	5min



DWARSKOP

1	S0051982	pastilles	dwarskop	chassis	4	C	CBM	CBM	0	0	4/4/1j	1j	2h
2	S 33602	slijtlatten (midden)	dwarskop	chassis	2	C	CBM	CBM	0	0	1/2/1j	2j	60min
3	S0045827	slijtlatten (buitenkant, beweegbare kop)	dwarskop	chassis	2	C	CBM	CBM	0	0	1/2/1j	2j	60min
4	S 35205	slijtlatten (vast)	dwarskop	chassis	4	C	CBM	CBM	0	0	1/4/1j	4j	60min
5	S 15661	membraan	dwarskop	vormkoppen	2	B	CBM	CBM	0	0	7/2/1j	4m	90min
6		pneumatiek membraan	dwarskop	vormkoppen	-	C	CBM	CBM	0	0	1/j	1j	60min
7		schokdempers	dwarskop	schokdempers	4	A	CBM	CBM	0	4/4/1j	9/4/1j	4m	30min
8		hydrauliek schokdempers	dwarskop	schokdempers	-	A	CBM	CBM	0	0	1/j	1j	60min
9		zzz PNEUMATIEK	dwarskop	schokdempers	-	A	CBM	CBM	0	0	1/j	1j	60min
10	S 18479	lichaam	dwarskop	stootblokken	2	C	BDM	BDM	0	0	3/2/1j	8m	60min
11		regelvijs	dwarskop	stootblokken	2	B	CBM	CBM	0	0	5/2/1j	5m	5min
12	S 16953	assen	dwarskop	loopwielen	24	B	BDM	BDM	0	5/24/1j	5/24/1j	30m	20min
13		kogellagers	dwarskop	loopwielen	24	B	BDM	BDM	0	5/24/1j	5/24/1j	30m	20min
14	S0041955	looplatten	dwarskop	loopwielen	2	B	CBM	CBM	0	0	4/2/1j	6m	3h

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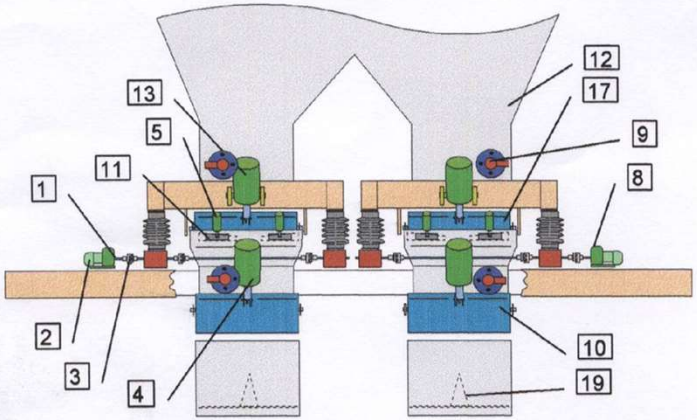
BDM (vervangen bij breuk)

ZANDTOEVOER



nr	S-Nr.	Omschrijving	Groep (aandrijving, hydraulisch, elektrisch,...)		#	ABC - class.	Soort Onderhoud*		Part-history				
							NU	LATER	# t.g.v. kinder-ziektes	# in bedrijfs-periode	# t.g.v. veroude-ring	MTBF (dagen)	MTTR (man-uren)
1		aandrijfas	zandtoevoer	doseur	4	C	BDM	BDM	0	0	0	?	4h
2		aandrijfmotor	zandtoevoer	doseur	2	C	BDM	BDM	0	0	0	?	60min
3		koppelingen	zandtoevoer	doseur	12	C	BDM	BDM	0	0	12/12/20j	20j	60min
4		luchtcilinder zandpoorten (onderste)	zandtoevoer	doseur	4	C	CBM	CBM	0	0	4/4/3j	3j	60min
5	S0065740	luchtcilinder zandschopjes	zandtoevoer	doseur	8	B	CBM	CBM	0	2/8/1j	4/8/1/j	16m	60min
6		pneumatiek luchtcilinders zandpoorten	zandtoevoer	doseur	-	C	BDM	BDM	0	0	1/j	1j	30min
7		pneumatiek luchtcilinders zandschopjes	zandtoevoer	doseur	-	B	BDM	BDM	0	1/j	2/j	4m	30min
8		reductoren	zandtoevoer	doseur	8	C	BDM	BDM	0	0	8/8/20j	20j	60min
9	S 15841	vibratoren	zandtoevoer	doseur	4	B	BDM	BDM	0	1/4/1/j	2/4/1j	16m	30min
10	S0044407	zandpoorten (onderste)	zandtoevoer	doseur	2	C	PRM	PRM	0	0	2/2/1j	1j	80h
11	S0064655	zandschopjes	zandtoevoer	doseur	8	B	CBM	CBM	0	4/8/1j	6/8/1j	10m	30min
12		blaasstenen	zandtoevoer	silo	8	C	BDM	BDM	0	0	4/8/1j	2j	60min
13		luchtcilinder zandpoorten (bovenste)	zandtoevoer	silo	4	C	CBM	CBM	0	0	4/4/3j	3j	60min
14		niveaumeter	zandtoevoer	silo	2	C	BDM	BDM	0	0	2/2/20j	20j	30min

EQP.-NR. **TL 60** (TL 63)

EQP.-NAAM: **Vormmachine**

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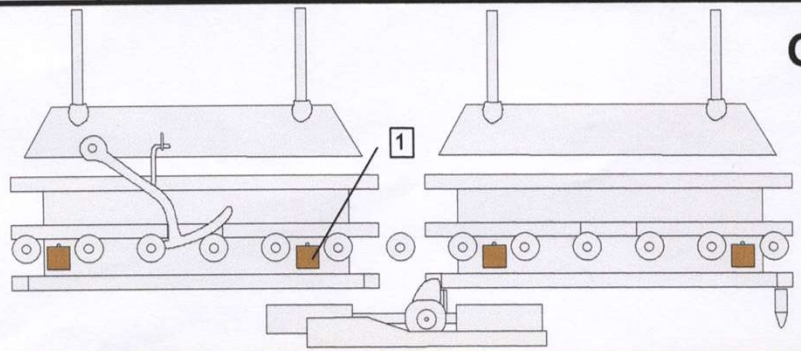
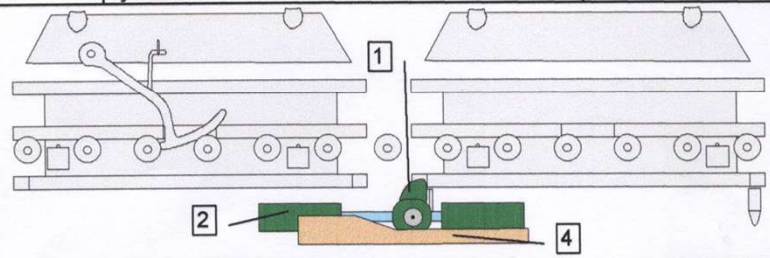
BDM (vervangen bij breuk)



ONTVORMCILINDERS

nr	S-Nr.	Omschrijving	Groep (aandrijving, hydraulisch, elektrisch,...)		#	ABC - class.	Soort Onderhoud*		Part-history				
							NU	LATER	# t.g.v. kinder-ziektes	# in bedrijfs-periode	# t.g.v. veroude-ring	MTBF (dagen)	MTTR (man-uren)
1	S0067590	cilinders	ontvormcilinders	cilinders	8	B	BDM	BDM	0	2/j	0/j	6m	15min
2		hydrauliek	ontvormcilinders	hydrauliek	-	B	BDM	BDM	0	0	1/5j	5j	60min



BACKSPACER

1	S 31450	haak	backspacer	haak	1	B	CBM	CBM	0	0	1/1/1j	1j	30min
2		cilinder	backspacer	cilinder	1	B	CBM	CBM	0	0	1/1/1j	1j	30min
3		pneumatiek	backspacer	pneumatiek	-	B	BDM	BDM	0	0	1/5j	5j	60min
4	S 18528	looplatten	backspacer	looplat	2	B	BDM	BDM	0	0	2/2/2j	2j	30min

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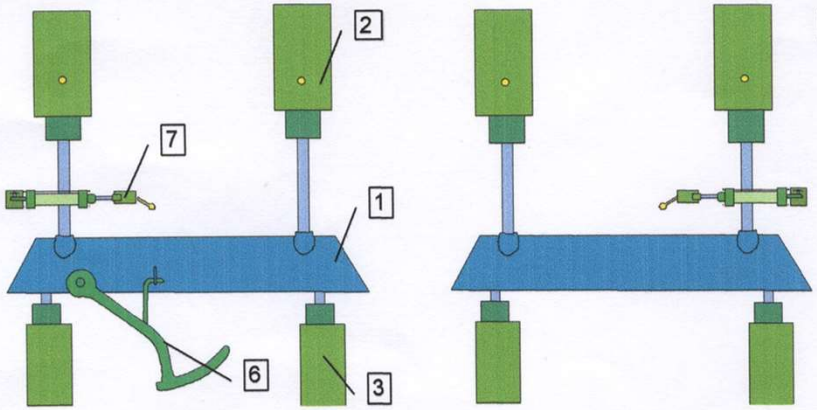
BDM (vervangen bij breuk)

nr	S-Nr.	Omschrijving	Groep (aandrijving, hydraulisch, elektrisch,...)		#	ABC - class.	Soort Onderhoud*		Part-history				
							NU	LATER	# t.g.v. kinder-ziektes	# in bedrijfs-periode	# t.g.v. veroude-ring	MTBF (dagen)	MTTR (man-uren)
15	S 16950	wielen	dwarskop	loopwielen	24	B	BDM	BDM	0	5/24/1j	5/24/1j	30m	20min
16		luchtcilinder	dwarskop	persluchtcilinder	1	A	CBM	CBM	0	0	1/1/3j	3j	16h
17		pneumatica	dwarskop	persluchtcilinder	-	A	BDM	BDM	0	1/3j	2/3j	1j	60min



UPSETS

1	S0056880	kader	upsets	kader	2	A	CBM	CBM	0	0	1/2/6j	12j	3h
2		achterste	upsets	pneumatische cilinders	2	A	CBM	CBM	0	0	2/2/1j	1j	1h
3		voorste	upsets	pneumatische cilinders	2	A	CBM	CBM	0	1/2/1j	2/2/1j	8m	1h
4		benaderingsschakelaars	upsets	pneumatische cilinders	2	A	BDM	BDM	0	2/2/6j	0	6j	10min
5		pneumatiek	upsets	pneumatische cilinders	-	A	BDM	BDM	0	0	1/6j	6j	60min
6	S0040150	kromme haak	upsets	kromme haak	1	A	CBM	CBM	0	10/1/1j	1/1/1j	1m	8 min
7		sproeiers lossingsmiddel	upsets	sproeiers lossingsmiddel	2	B	BDM	BDM	0	12/2/1j	0/2/1j	1m	15min

EQP.-NR. **TL 60** (TL 63)

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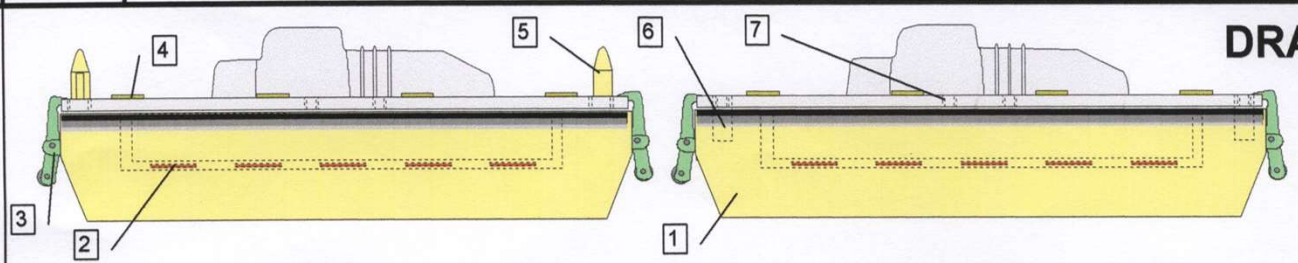
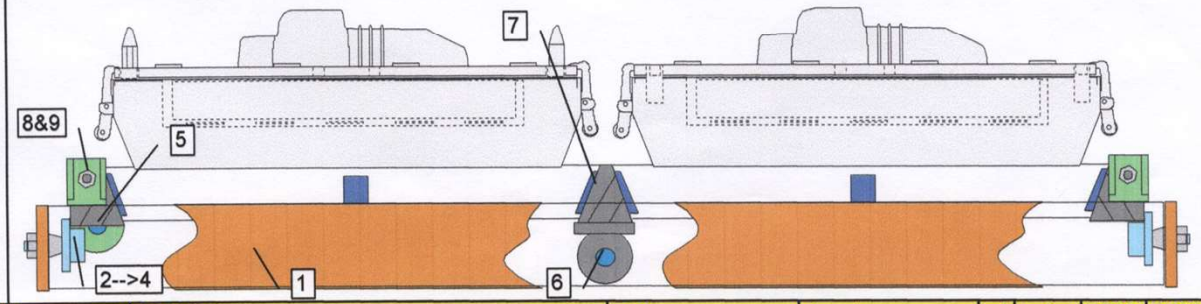
nr	S-Nr.	Omschrijving	Groep (aandrijving, hydraulisch, elektrisch,...)		#	ABC - class.	Soort Onderhoud*		Part-history				
							NU	LATER	# t.g.v. kinder-ziektes	# in bedrijfs-periode	# t.g.v. veroude-ring	MTBF (dagen)	MTTR (man-uren)
1		blok	draagkaders	blok	4	B	BDM	BDM	0	0	0	50j	15min
2		steunplaatjes	draagkaders	steunplaatjes	80	C	BDM	BDM	0	0	80/80/40j	40j	10min
3		klamhaken	draagkaders	klamhaken	16	A	CBM	CBM	1/16/1j	10/16/1j	1/16/1j	16m	10min
4	S 17117	paddestoelen	draagkaders	paddestoelen	48	C	CBM	CBM	0	0	1/j	1j	10min
5		pinnen kasten	draagkaders	pinnen kasten	4	A	CBM	CBM	0	1/4/10d	3/4/5d	1w	5min
6		bussen kasten	draagkaders	bussen kasten	4	A	CBM	CBM	0	1/4/10d	3/4/5d	1w	5min
7		pinnen modelplaten	draagkaders	pinnen modelplaten	12	A	CBM	CBM	0	0	12/12/1j	1j	5min
1		chassis	tafel	chassis	1	A	BDM	BDM	0	1/1/5j	0	5j	2h





Examples of Planned Maintenance Goals

Indicator	Improvement goal
Failures by equipment ranking	• AA equipment → 0 • A equipment → 0 • B equipment → 1/2 of baseline 1/2 • C equipment
Failures by failure ranking	• Major failures → 0 • Intermediate failures → 1/10 of baseline 1/10 • Minor failures → 1/2 of baseline 1/2
Process failures	• Leaks, contamination, and blocks → 0 • Abnormal pressures, temperatures, and flow rates due to complex causes → 1/2 of baseline
Equipment failure severity	$\frac{\text{Failure downtime}}{\text{Operating time}} \times 100$ → (AA equipment : 0) (A equipment : 0.15 or less)
Equipment failure frequency	$\frac{\text{Failure stops}}{\text{Operating time}} \times 100$ → (AA equipment : 0) (A equipment : 0.1 or less)
PM achievement rate	$\frac{\text{PM jobs completed}}{\text{Total planned maintenance Jobs scheduled}} \times 100$ → (90% or more)

Necessary Accomplishments for Process-Competent Operators

Level 1

- **Understands process performance and functions**
- **Operates Process correctly**

Level 2

- **Understands properties of materials being handled**
- **Performs correct adjustment and setting**

Level 3

- **Detects abnormalities promptly**
- **Takes emergency action against abnormalities**

Level 4

- **Recognizes signs of abnormality**
- **Deals with abnormalities correctly**
- **Performs periodic overhaul checking and parts replacement correctly**

Support for Autonomous Maintenance

- Provide instruction in inspection skills and help operators prepare inspection standards (checkpoints, checking intervals, and so on)

- Provide training in lubrication techniques, standardize lubricant types, and help operators to formulate lubrication standards (lubrication points, lubricant types, intervals, and so on)

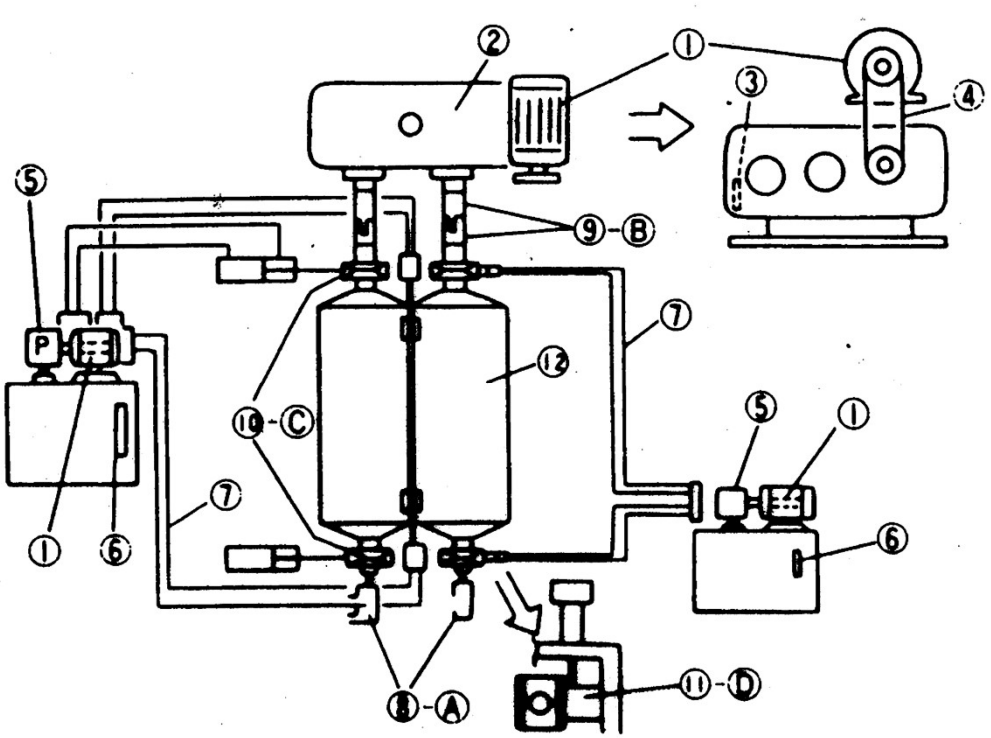
- Deal quickly with deterioration, minor flaws in equipment conditions, and deficiencies in basic equipment conditions (i.e., carry out maintenance work identified by operators promptly).

Support for Autonomous Maintenance

- Contribute technical assistance in improvement activities such as eliminating contamination sources, making areas more accessible for cleaning, lubrication, and inspection and boosting equipment effectiveness.

- Organize routine activities (morning meetings, rounds to take orders for maintenance tasks, and so on).

Check Situations



Check marks :

○ : Normal

◎ : Lubricated

△ : Questionable

× : Nor normal

Harmful Effects of Inadequate Cleaning

Failure	**Dirt and foreign penetrates rotating parts, sliding parts, pneumatic and hydraulic systems, electrical control systems, and sensors, etc., causing loss of precision, malfunction, and failure as a result of wear, blockage, frictional resistance, electrical faults, etc.**
Quality Defects	**Quality defects are caused either directly by contamination of the product with foreign matter or indirectly as a result of equipment malfunction.**
Accelerated Deterioration	**Accumulated dust and grime make it difficult to find and rectify cracks, excessive play, insufficient lubrication, and other disorders, resulting in accelerated deterioration.**
Speed Losses	**Dust and dirt increase wear and frictional resistance, causing speed losses such as idling and underperformance.**

Exposing Seven Types of Abnormality

Abnormality	Examples
1.Minor Flaws	
• Contamination	Dust, dirt, powder, oil, grease, rust, paint
• Damage	Cracking, crushing, deformation, chipping, bending
• Play	Shaking, failing out, titling, eccentricity, wear, distortion, corrosion
• Slackness	Belts, chains
• Abnormal phenomena	Unusual noise, overheating, vibration, strange smells, discoloration, incorrect pressure
• Adhesion	or current Blocking, hardening, accumulation of debris, peeling, malfunction
2.Unfulfilled Basic Conditions	
• Lubrication	Insufficient, dirty, unidentified, unsuitable, or leaking lubricant
• Lubricant supply	Dirty, damaged, or deformed lubricant inlets, faulty lubricant pipes
• Oil level gauges	Dirty, damaged, leaking; no indication of correct level
• Tightening	Nuts and bolts: slackness, missing, cross-threaded, too long, crushed, corrected, washer unsuitable, wing nuts on backward
3.Inaccessible Places	
• Cleaning	Machine construction, covers, layout, foothold, space
• Checking	Covers, construction, layout, instrument position and orientation, operating-range display
• Lubricating	Position of lubricant inlet, construction, height, footholds, lubricant outlet, space
• Tightening	Covers, construction, layout, size, footholds, space
• Operation	Machine layout; position of valves, switches, and levers; footholds
• Adjustment	Position of pressure gauges, thermometers, flow meters, moisture gauges, vacuum gauges,etc.

Exposing Seven Types of Abnormality

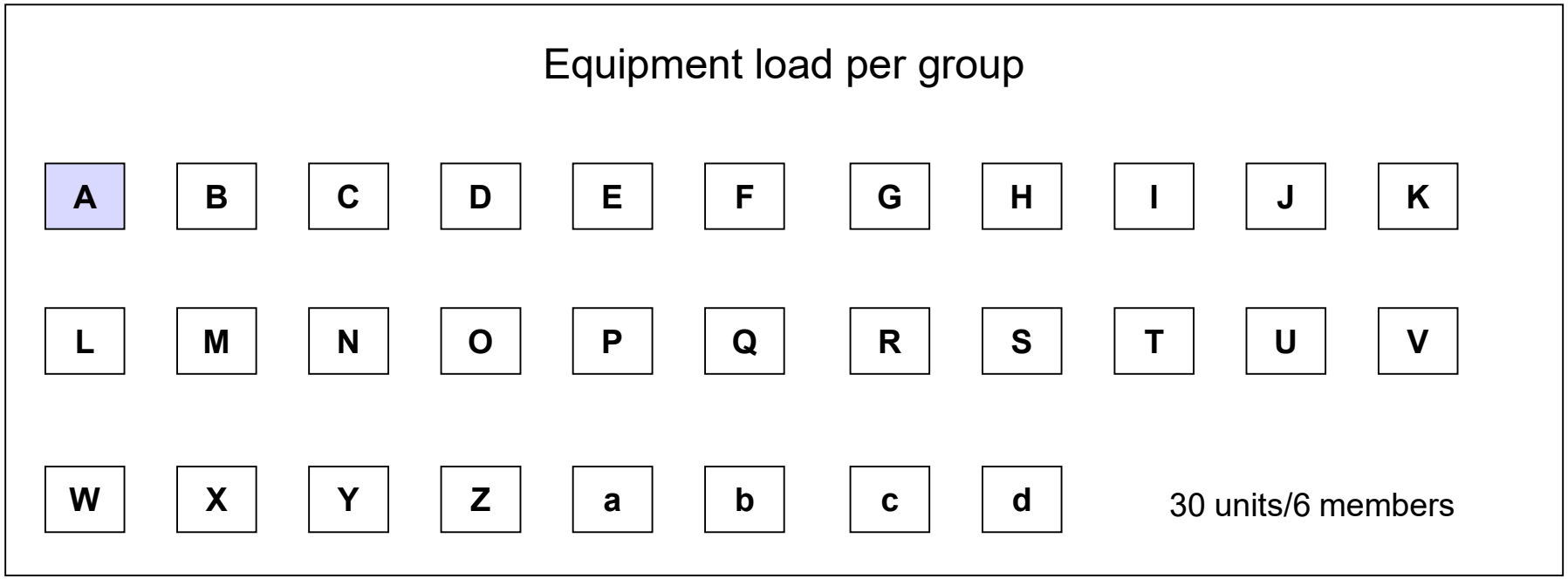
Abnormality	Examples
4.Contamination Sources	
• Product	Leaks, spills, spurts, scatter, overflow
• Raw materials	Leaks, spills, spurts, scatter, overflow
• Lubricants	Leaking, spill, and seeping lubricating oils, hydraulic fluids, fuel oil, etc.
• Gases	Leaking compressed air, gases, steam, vapors, exhaust fumes, etc.
• Liquids	Leaking, spilt and spurting cold water, hot water, half-finished products, cooling water,
• Scrap	waste water, etc.
• Other	Flashes, cuttings, packaging materials, and nonconforming product
	Contaminants brought in by people, fork-lift trucks, etc. and infiltrating through cracks in building
5.Quality Defect Sources	
• Foreign matter	Inclusion, infiltration, and entrainment of rust, chips, wire scraps, insects, etc.
• Shock	Dropping, jolting, collision, vibration
• Moisture	Too much, too little, infiltration, defective elimination
• Grain size	Abnormalities in screens, centrifugal separators, compressed-air separators, etc.
• Concentration	Inadequate warming, heating, compounding, mixing, evaporation, stirring, etc.
• Viscosity	Inadequate warming, heating, compounding, mixing, evaporation, stirring, etc

Exposing Seven Types of Abnormality

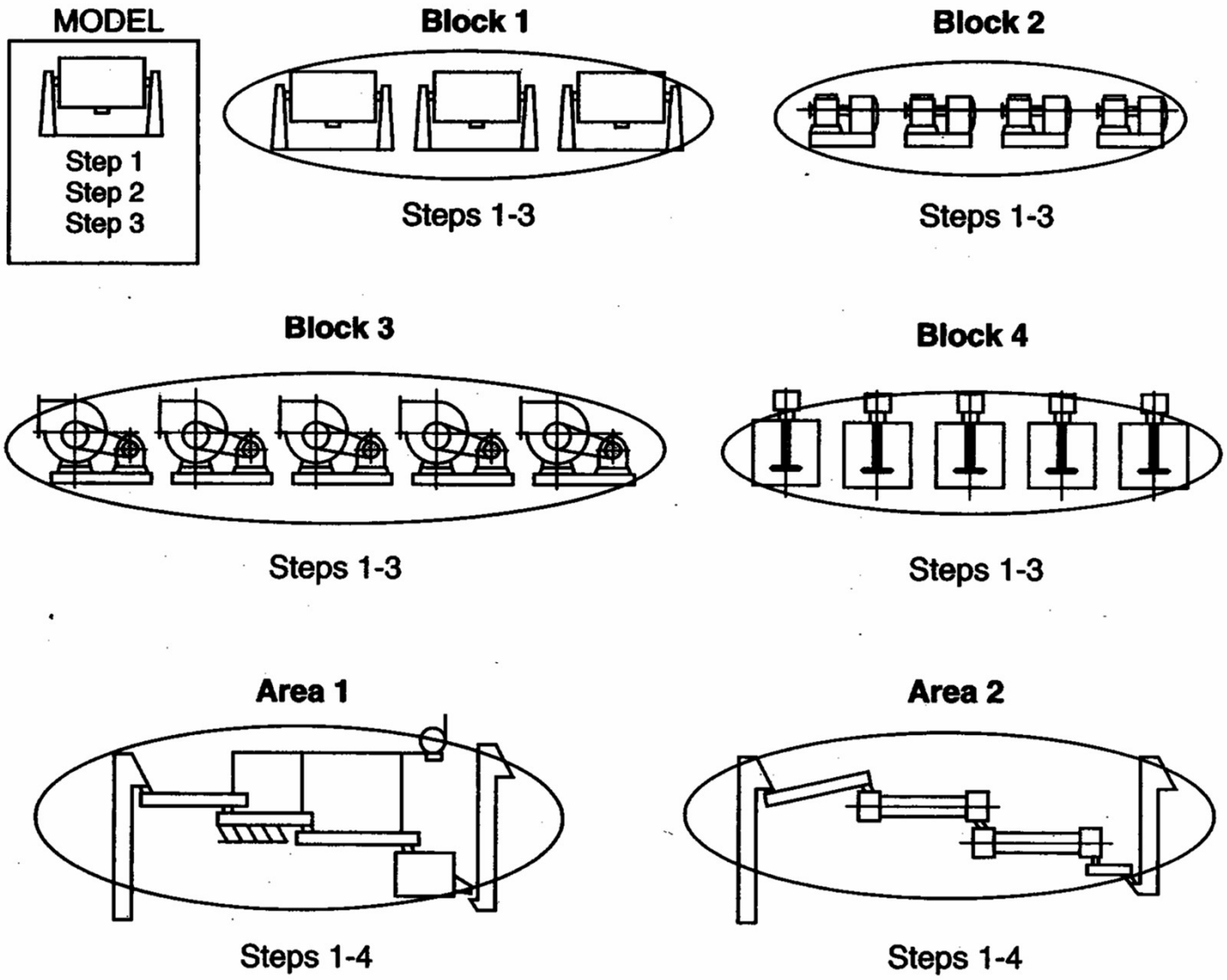
Abnormality	Examples
6.Unnecessary and Non-urgent items • Machinery • Piping equipment • Measuring instruments • Electrical equipment • Jigs and tools • Spare parts • Makeshift repairs	Pumps, fans, compressors, columns, tanks, etc. Pipes, hoses, duct, valves, dampers, etc. Temperatures, pressure gauges, vacuum gauges, ammeters, etc. Wiring, piping, power lead, switches, plugs, etc. General tools, cutting tools, jigs, molds, dies, frames, etc. Standby equipment, spares, permanent stocks, auxiliary materials, etc. Tape, string, wire, metal plates, etc.
7.Unsafe places • Floors • Steps • Lights • Rotating machinery • Lifting gear • Other	Unevenness, tramps, projections, cracking, peeling, wear (steel deck plates) Too steep, irregular, peeling anti-slip covering, corrosion, missing handrails Dim, out of position, dirty or broken covers, not properly explosion-proofed Displaces, fallen off or broken covers, no safety or emergency stop devices Wires, hooks, brakes, and other parts of cranes and hoists Special substance, solvents, toxic gases, insulating materials, danger signs protective clothing, etc.

Model-Block-Area Deployment

How to implement PM in such a case as follows :



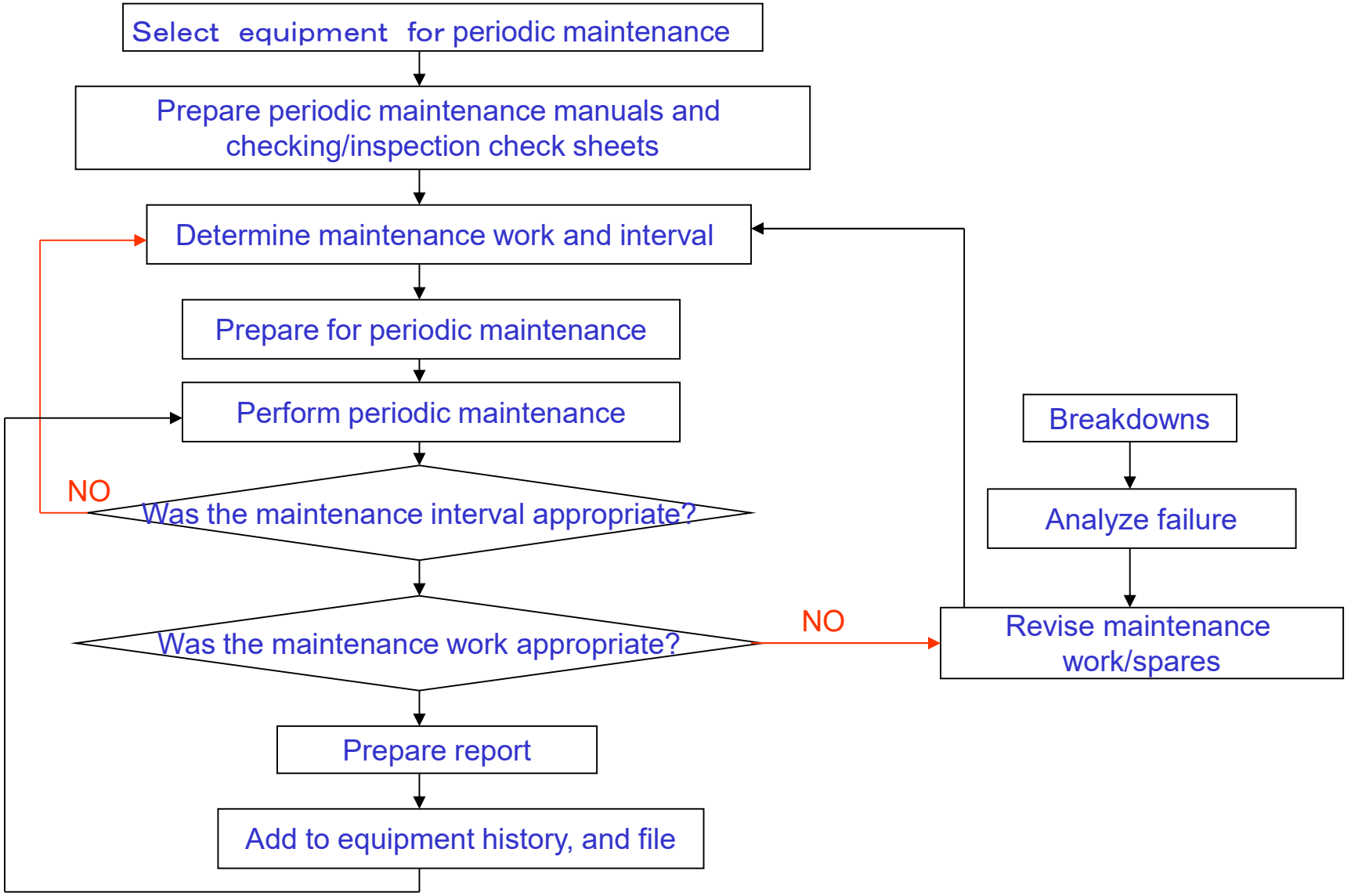
Model-Block-Area Deployment



Evaluation of the progress of PM

Evaluation item \ Equipment		1	2	3	
Rank		AA, A, B, C		AA, A, B, C	
What step of A.M.?		1 2 3 4	1 2 3 4	1 2 3 4	
Restoration of the equipment					
Sporadic breakdown/M					
Existence of maintenance standards	Cleaning, lubrication, inspection standards (manufacturing)				
	Equipment maintenance standards (maintenance dept.)				
Arrangement of a PM calendar					
Overall evaluation		1 2 3 4	1 2 3 4	1 2 3 4	

Periodic Maintenance Flow Diagram



Determination of Replacement Period (Example)

Introduction of equipment

Grasp the optimal conditions of equipment from past experiences, estimation, similarity of equipment data, etc.

Determination of period for replacement

Replacement standards

Part	Item	Method	Judgment standards	Period		
				D	W	M

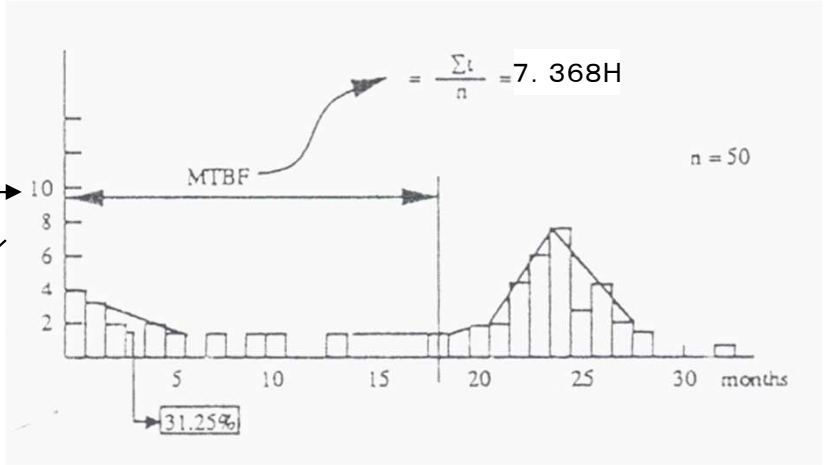
Implementation

Sporadic accident

Maintenance record

Maintenance data

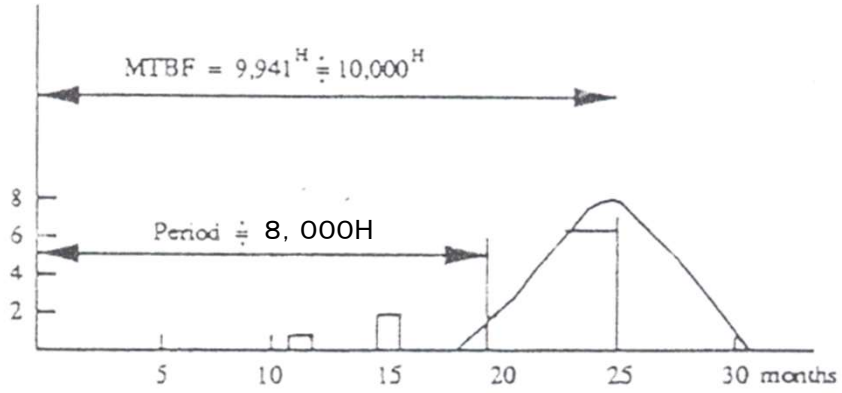
Analysis



Improvement of problems

(Corrective maintenance)
Group activities

Determination of the period



Consideration of costs for different cycles of parts

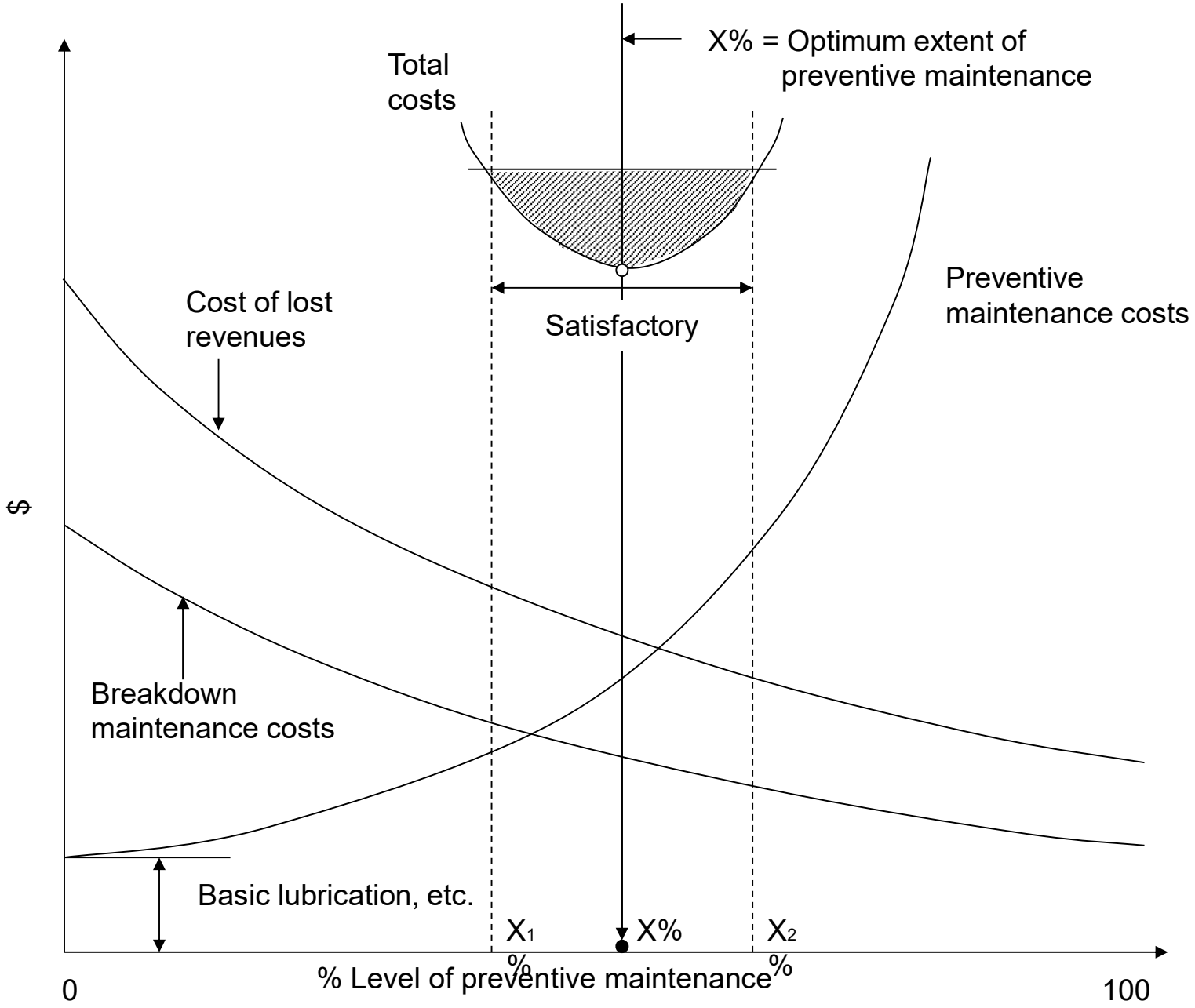
Extension of the period

(Corrective maintenance)

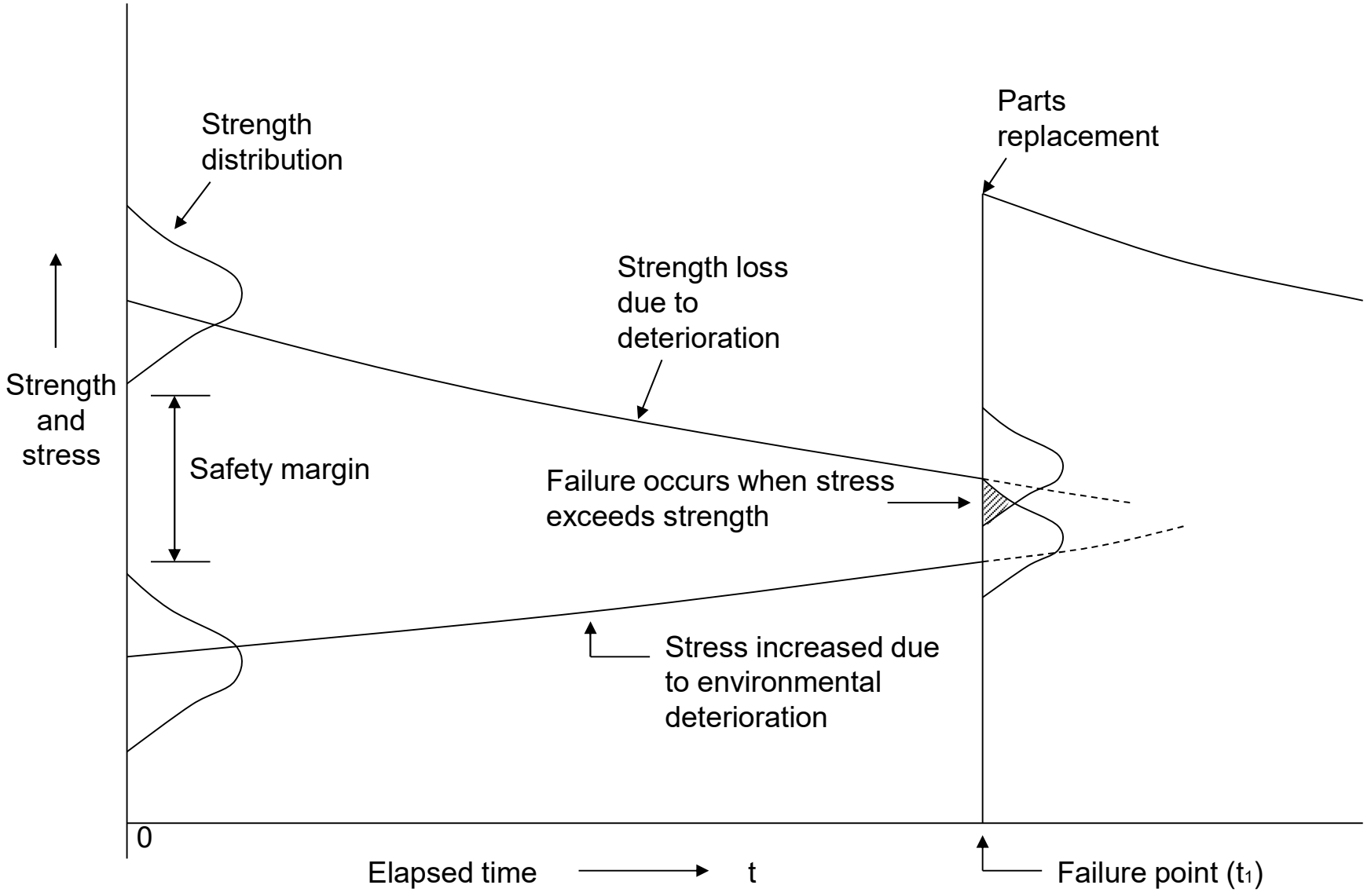
	Item	Contents
MTBF	1. Materials 2. Structure (Lubrication)	
σ	1. Creation of process accuracy 2. Review of process accuracy	

Determination of the review period

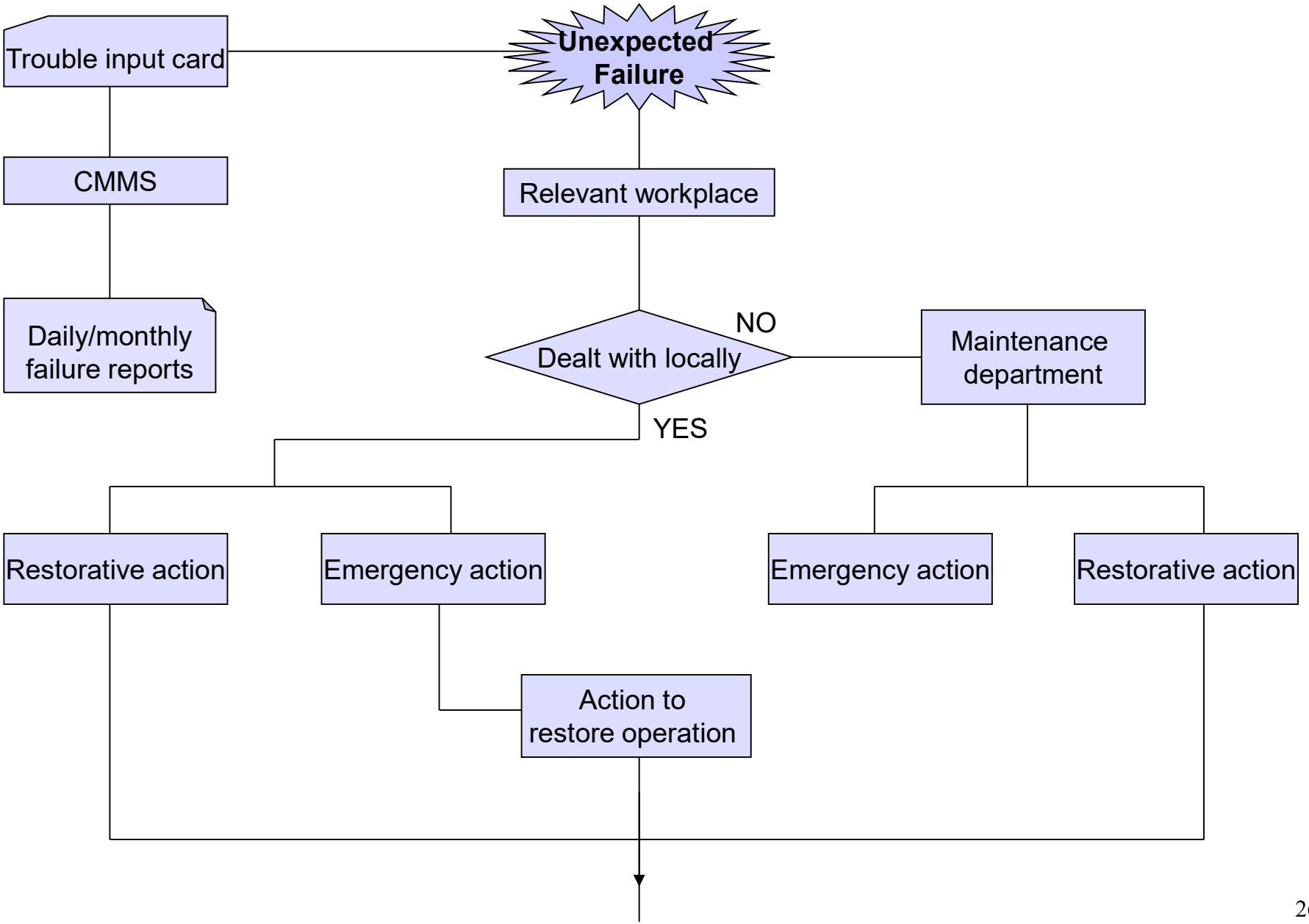
The relationship between cost and amount of preventive maintenance.



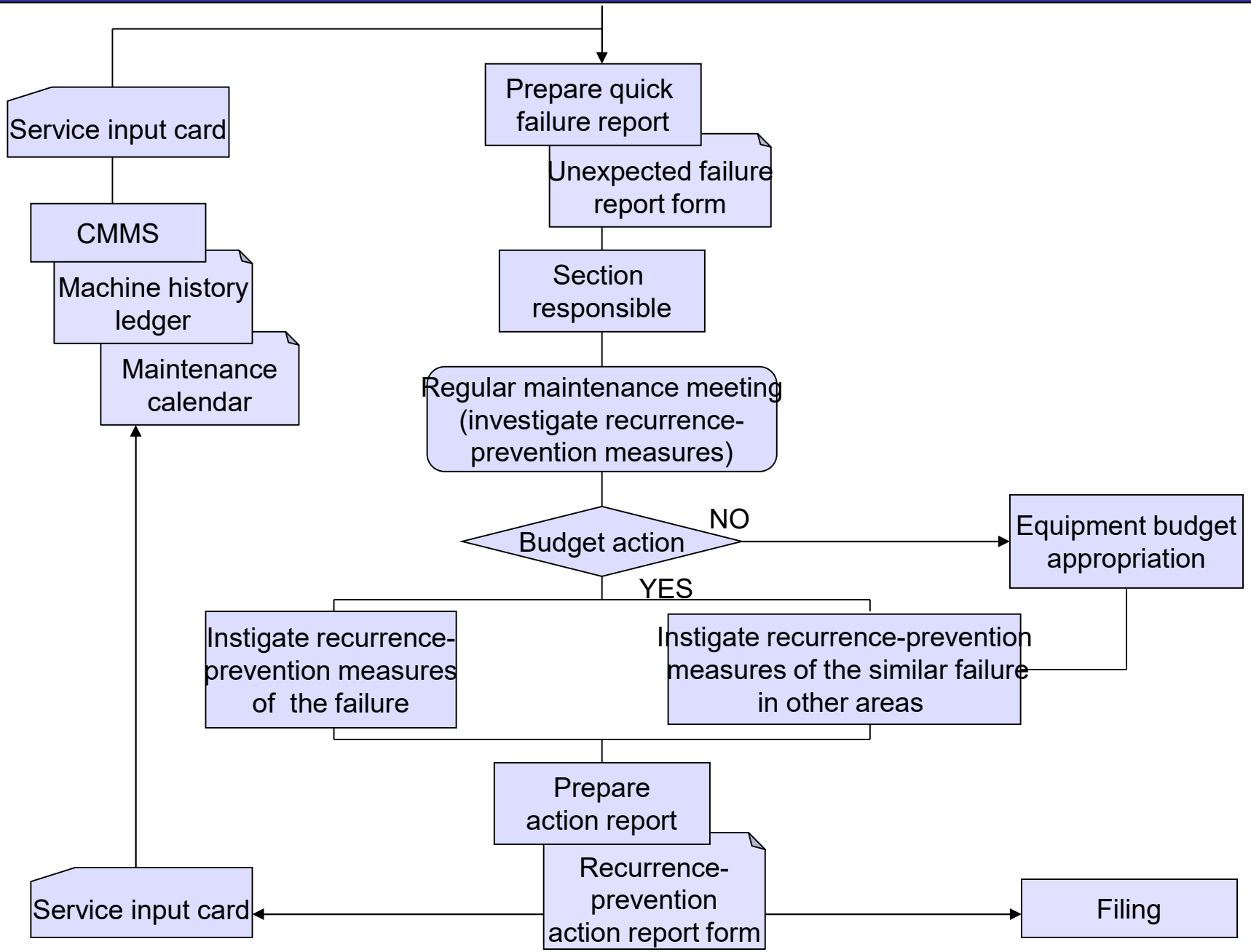
Equipment Deterioration



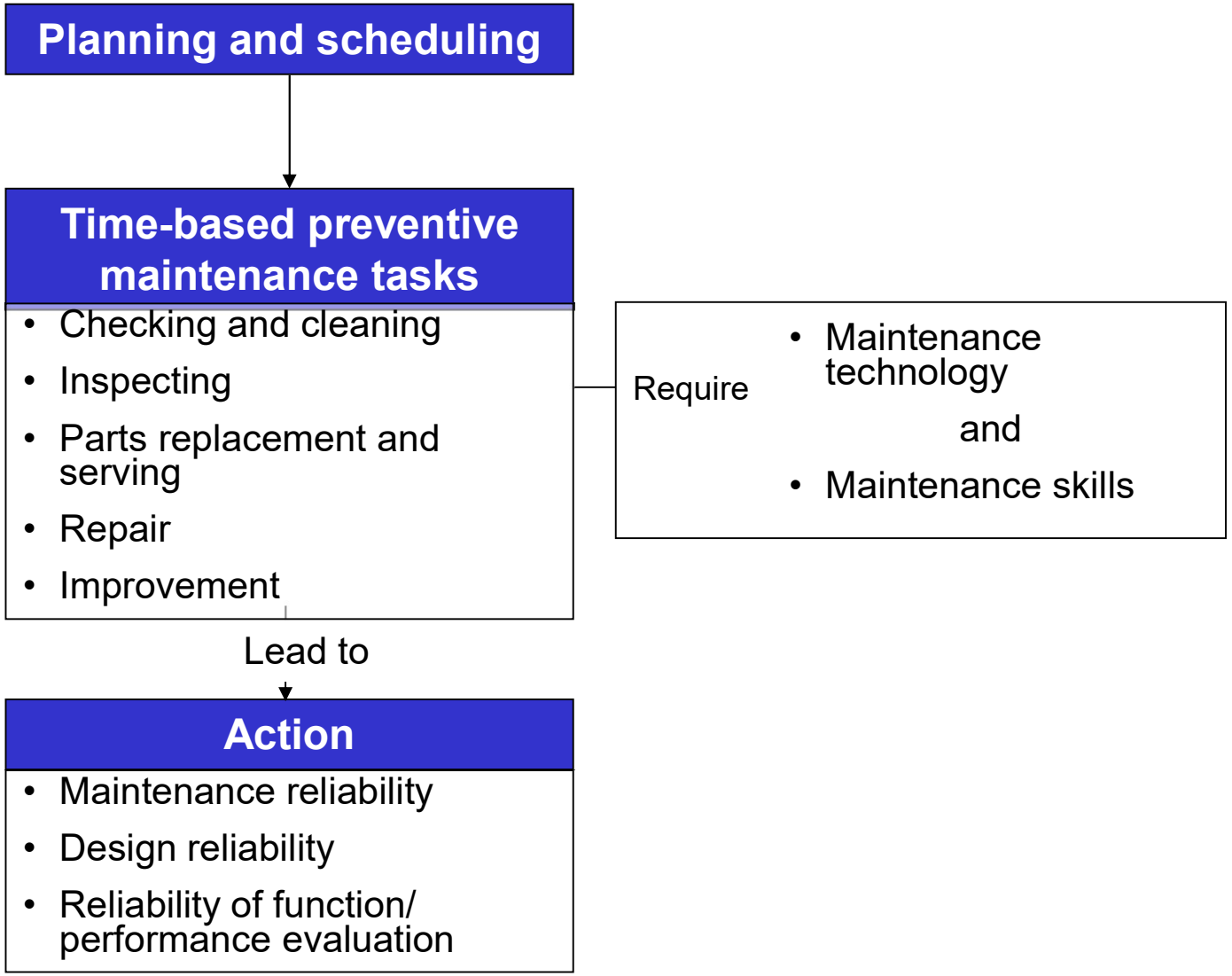
Flow Diagram for Preventing Recurrence of Unexpected Failures



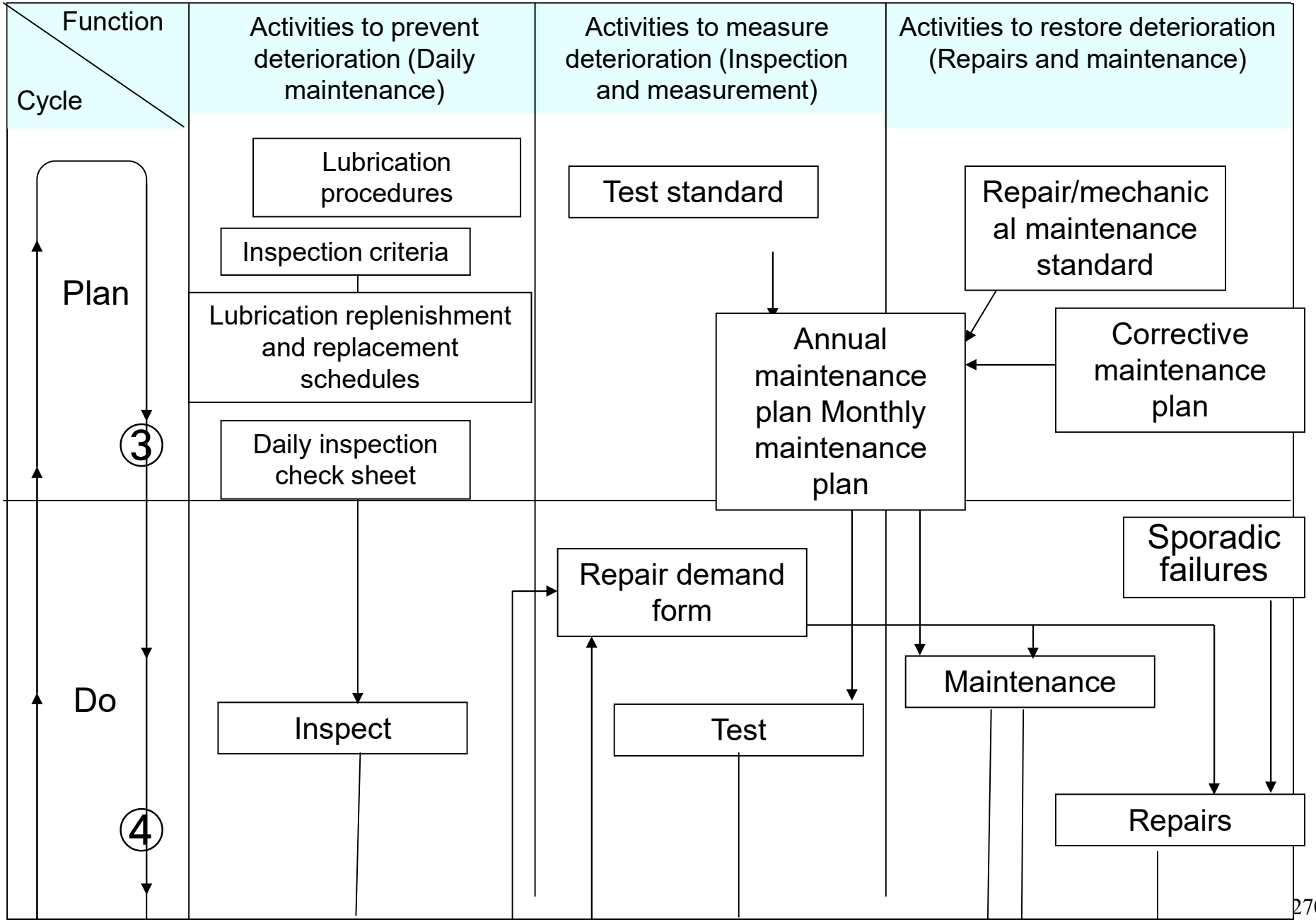
Flow Diagram for Preventing Recurrence of Unexpected Failures

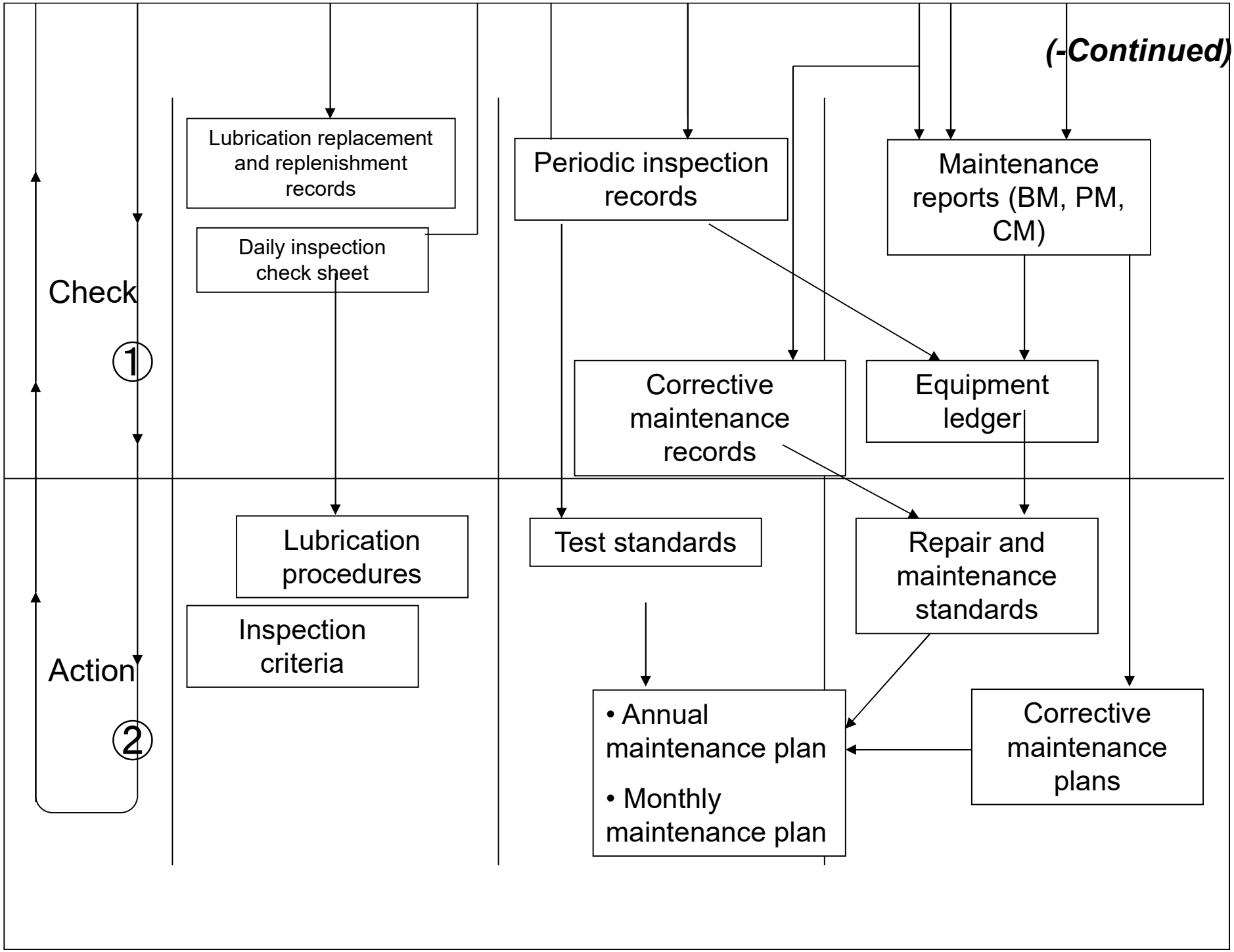


Preventive Maintenance Tasks in TBM

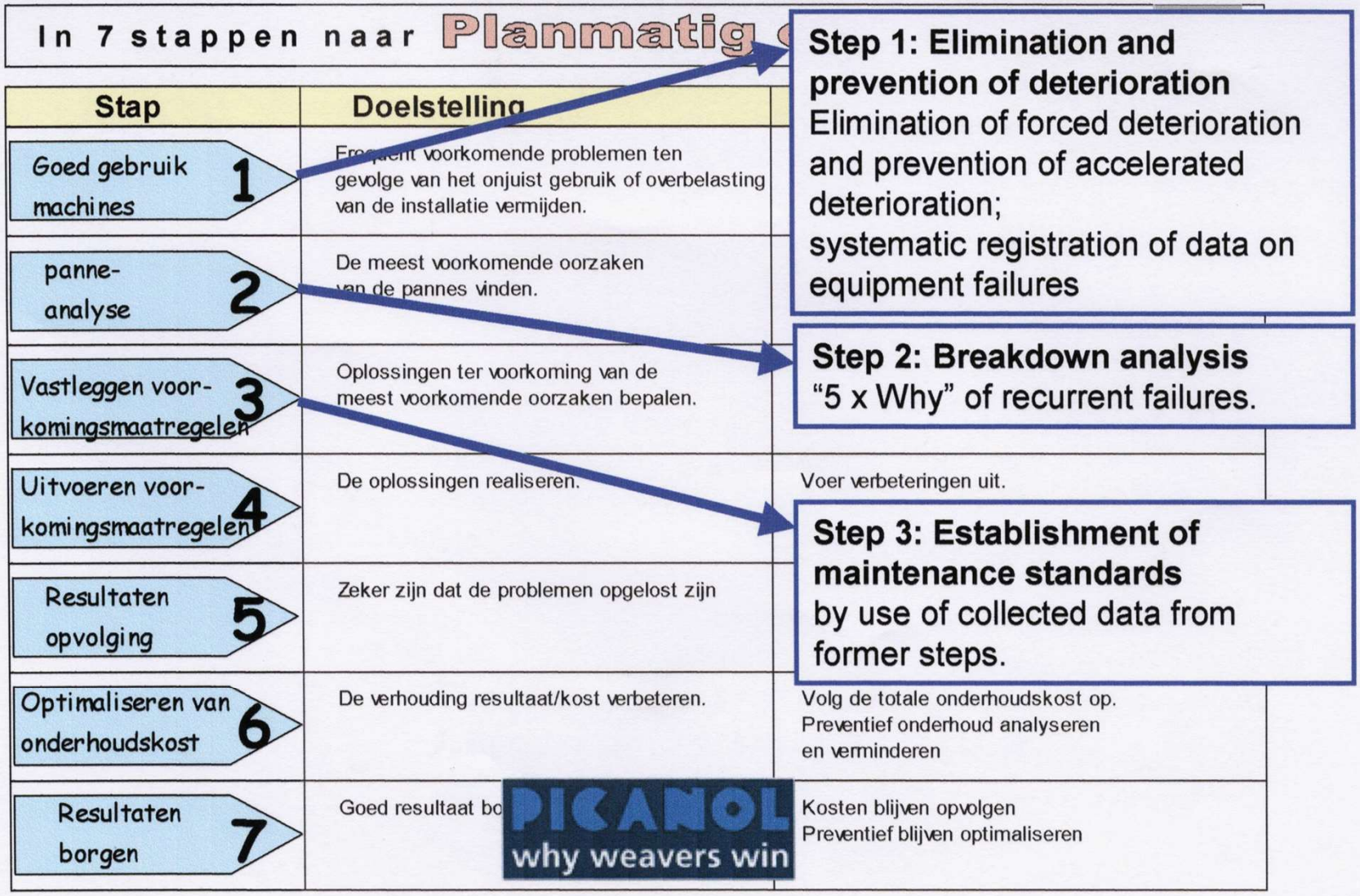


Failure and Maintenance Information

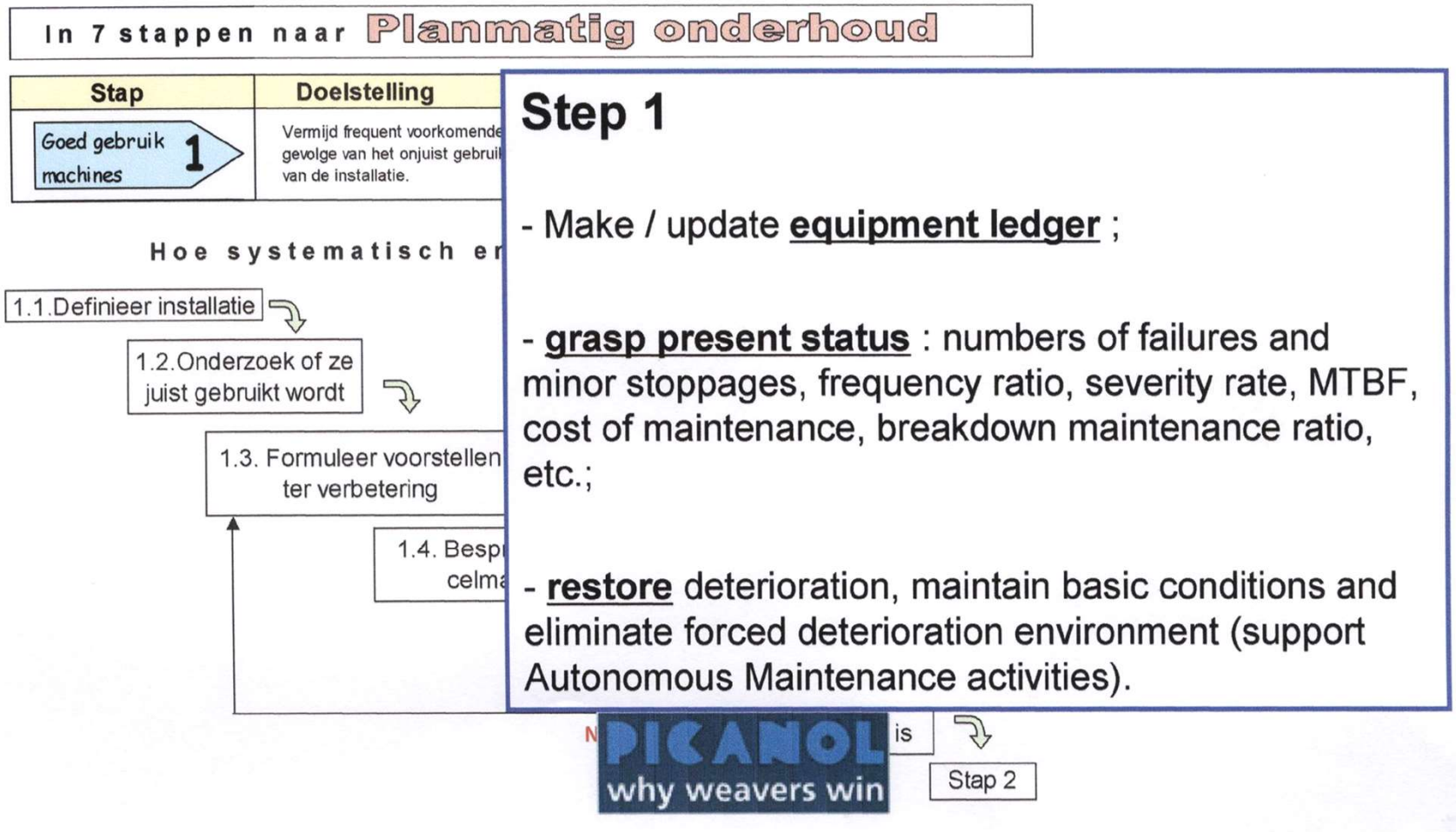



(-Continued)
Lubrication replacement and replenishment records
Daily inspection check sheet
Periodic inspection records
Maintenance reports (BM, PM, CM)
Check
①
Corrective maintenance records
Equipment ledger
Lubrication procedures
Inspection criteria
Test standards
Repair and maintenance standards
Action
②
• Annual maintenance plan
• Monthly maintenance plan
Corrective maintenance plans

PM – Planned maintenance



PM – Step 1: Elimination & prevention of deterioration



PM – Step 1

Expanded Bill of Materials - SHW

S-nr.	Description	#	Unit	ABC - class.	Type of Maintenance	Part-history					TBM	CBM
						Initial failure	chance failure	wear failure	MTBF / deviation (cal.days)	MTTR / deviation (hours)	Period P.M.	
	1. X-AS											
	1.1 AANDRIJVING											
S0068008	SIEM 1FT6108-8AC71-4AH1	1	S	AA	BM							
S0068009	TANDRIEM GT2 1000-8M-50	1	S	C	TBM							
S0068011	TANDRIEMPOLIE Z=53 GT2 50	1	S	C	BM							
S0068010	TANDRIEMPOLIE Z=86 GT2 50	1	S	C	BM							
S0068012	SPANBUS SPIETH DSM 38.1	1	S	C	BM							
S0068016	INA ASSCHIJF WS 81128	2	S	C	BM							
S0068017	INA NAALDKOOI K 81128 TN	2	S	C	BM							
S0068019	NADELKRANZ KKBF 4030 0452	2	S	C	BM							
S0068020	STELMOER SPIETH MSR 140X3	1	S	C	BM							
	.											
	1.2 MEETSYSTEEM											
S0068032	HEIDENH MEETLATBEHUIZING	1	S	B	BM							
S0068033	HEIDENH MEETLATBEHUIZING	3	S	B	BM							
S0068034	HEIDENH LAT LB302/LB382C	1	S	B	BM							
S0068035	HEIDENH LEESKOP LB382C	1	S	B	BM							
S0068036	HEIDENH KABEL LS186/LB381	1	S	B	BM							
	1.3 NOKKENDOOS											
S0068037	EUCHNER SN02D12-508	1	S	A	CBM							
	1.4 BLINDAGE											
S0068038	STAHLABDECKUNG X-AS LINKS	1	S	A	CBM							
S0068039	STAHLABDECKUNG X-AS RECHT	1	S	A	CBM							
	1.5 SPINDELASONDERSTEUNING											

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Expanded Bill of Materials - Kekeisen

PM – Step 1

S-Nr.	Description	#	Unit	ABC - class.	Type of Maintenance	Part-history					TBM	CBM
						Initial failure	chance failure	wear failure	MTBF / deviation (cal.days)	MTBR / deviation (hours)	Period P.M.	
	X-as											
	1. X-AS											
	1.1 AANDRIJVING											
S0068424	SIEM 1FT6105-8AF71-3AG0	1	S	A	BM							
S0068589	ZAHNSCHEIBE040100009A33	1	S	B	BM							
S0068632	ZAHNSCHEIBE 040090003A33	1	S	B	BM							
S0068633	ZAHNRIEM GT-8M-800-36	1	S	A	TBM							
S0068590	TLK 300.4203.038.001	3	S	C	BM							
	1.2 MEETSYSTEEM											
	HEIDENHAIN LS186C-ML1340	1	S	AA	PM							
S0068513			S									
	1.3 AFSCHERMINGEN		S									
S0067339	TELESKOPABDECKUNG XAS RE	1	S	A	BM							
S0067346	TELESKOPABDECKUNG XAS LI	1	S	A	BM							
S0066288	FEDER TELESKOPABDECKUNG X	1	SE	B	TBM							
	2. Y-AS											
	2.1 AANDRIJVING											
S0068424	SIEM 1FT6105-8AF71-3AG0	1	S	A	BM							
S0068589	ZAHNSCHEIBE040100009A33	1	S	B	BM							
S0068590	TLK 300.4203.038.001	1	S	B	BM							
S0068600	ZAHNRIEM GT 8M-720-36	1	S	A	TBM							
	2.2 MEETSYSTEEM											
S0068515	HEIDENHAIN LS186C ML740											

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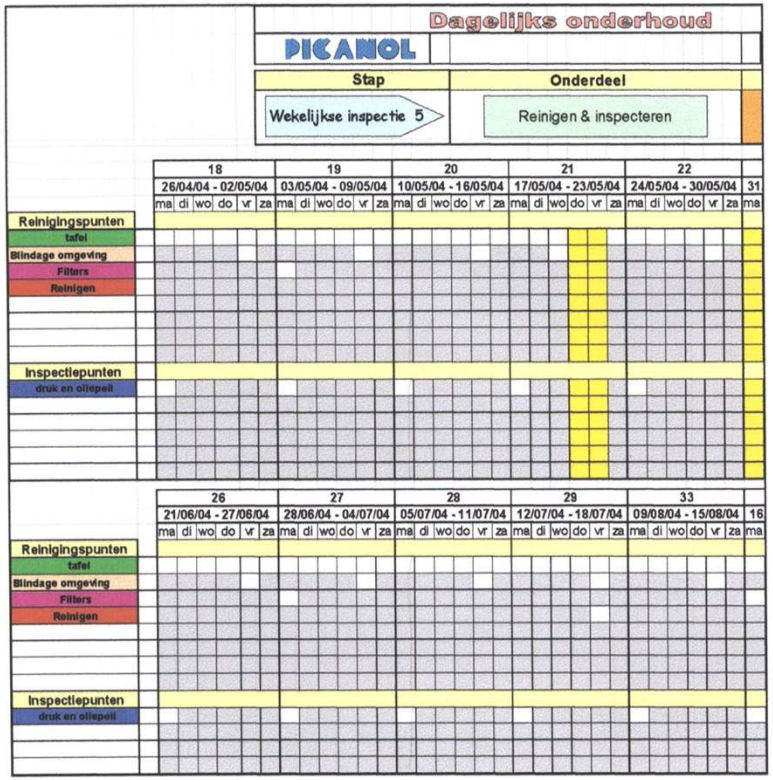
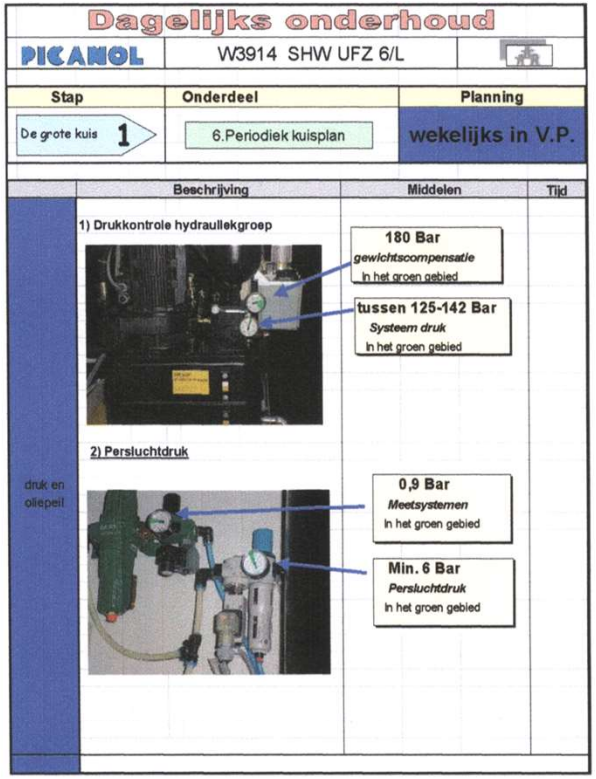
PM – Step 1

Support of Autonomous Maintenance





Autonomous maintenance modules and small technical inspections for operators

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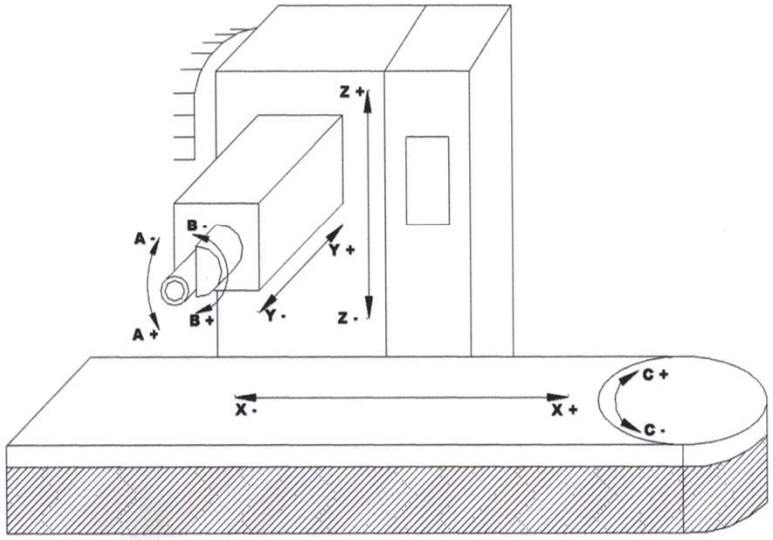
PM – Step 1

Support of Autonomous Maintenance

Instruction manual for operators made by operator Luc Verschoot.

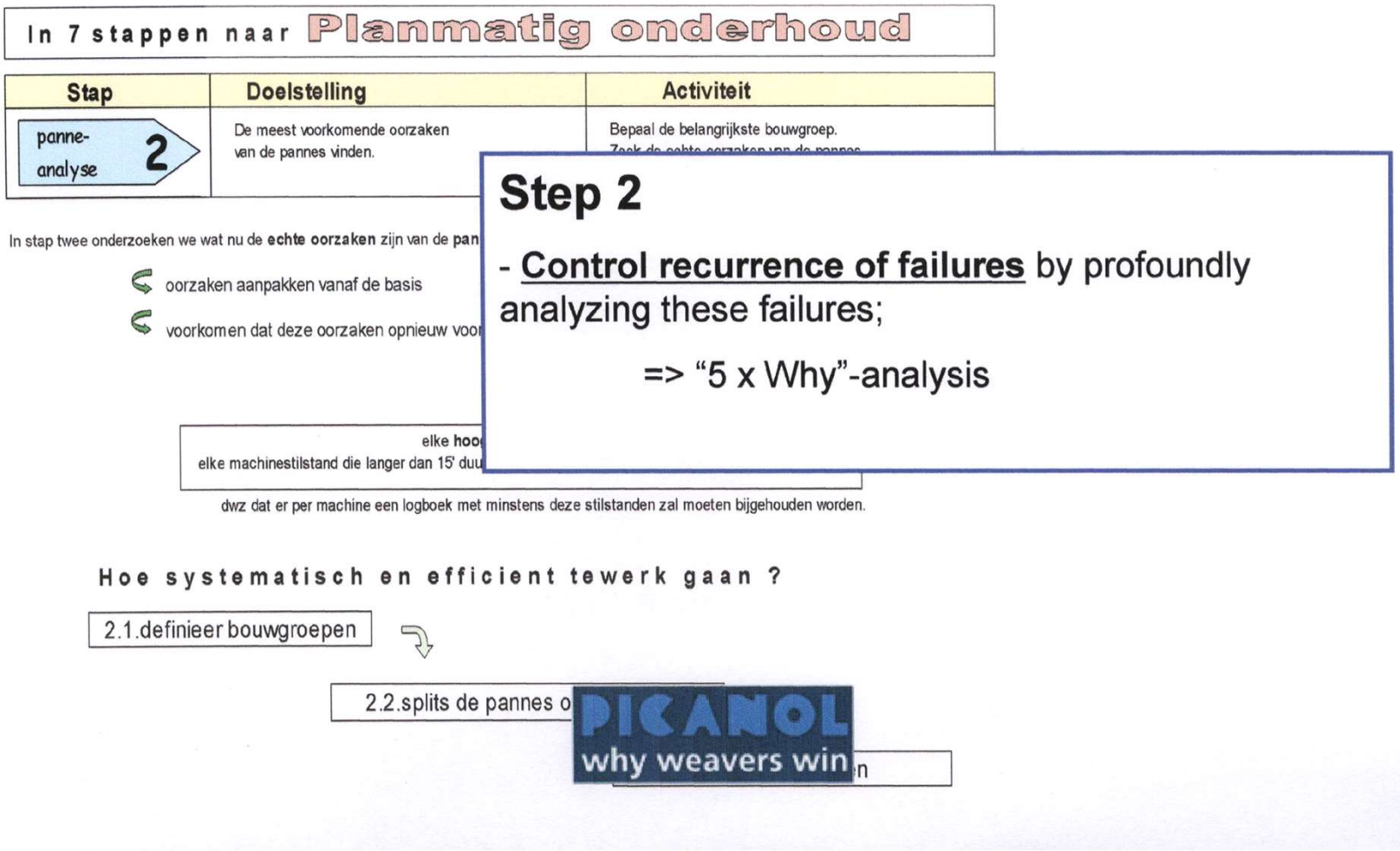


PM – Step 1

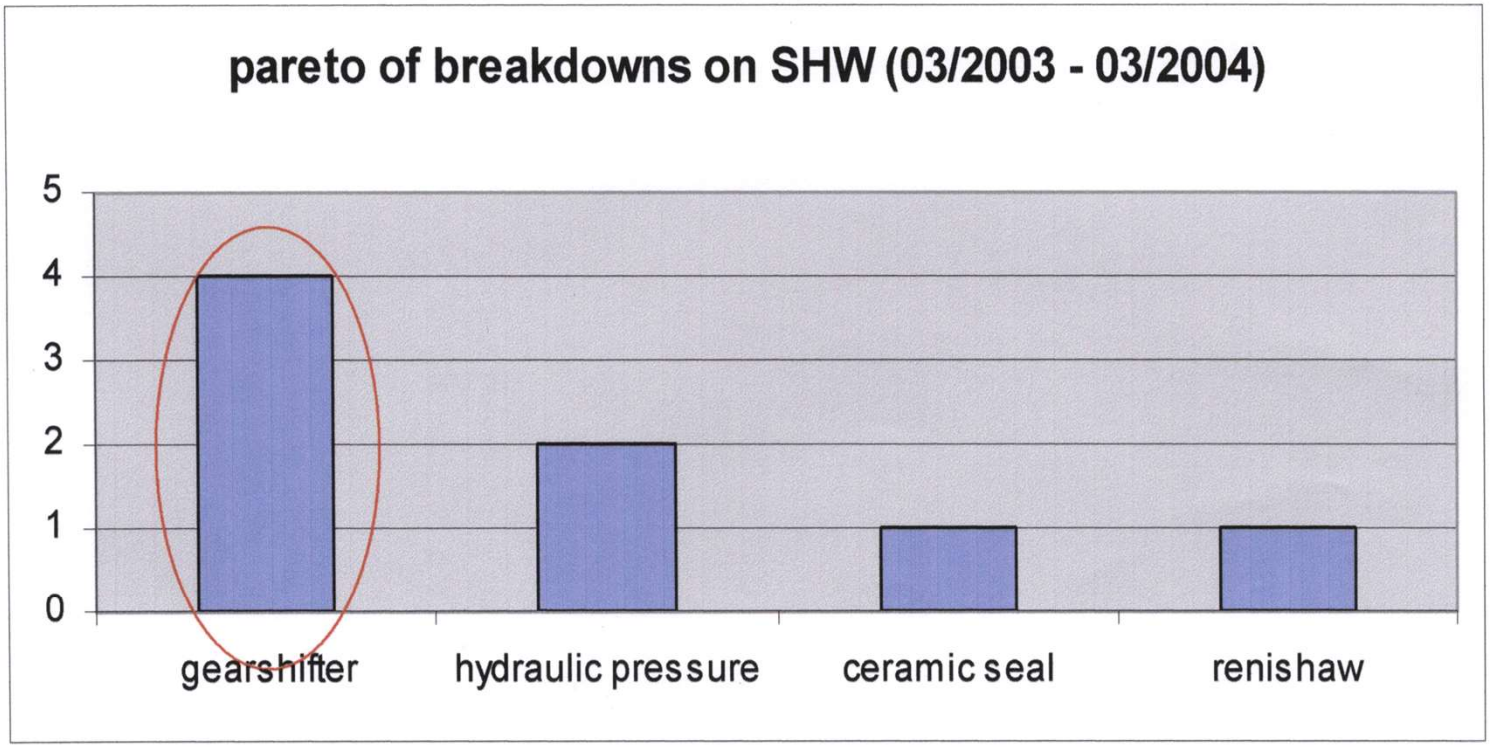
Support of Autonomous Maintenance

Instruction manual for operators made by operator Luc Verschoot.

PM – Step 2
Breakdown analysis



PM – Step 2
Breakdown analysis



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PM – Step 2

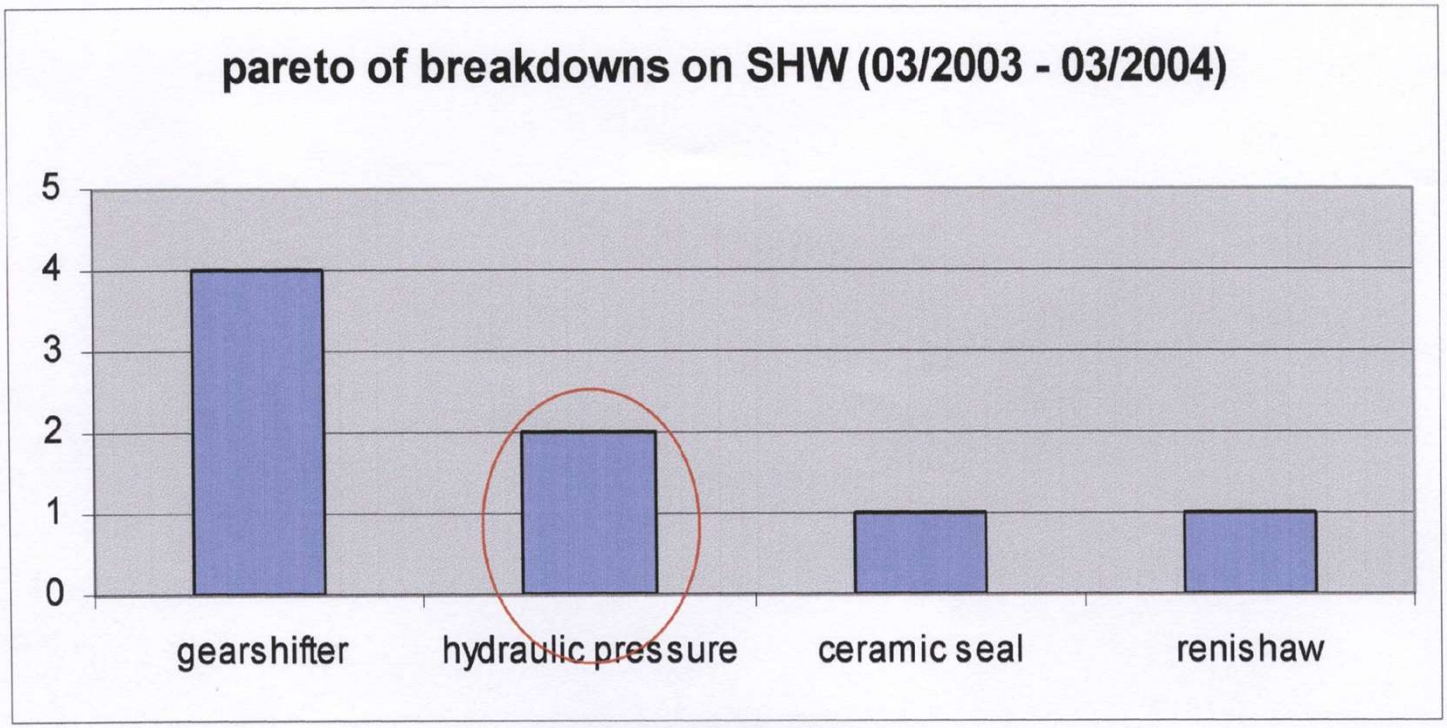
"5 x Why": Gearshifter

Problem: alarm 086 - 8ste as niet geklemd.

- After performing a gearchange, machine shuts down.
- Control does not detect a correct gearchange
- Switch does not send a signal to control after gearchange.
- Bad quality of switches.

Action taken: Replacement of switches by other brand in cooperation with constructor.

PM – Step 2
Breakdown analysis



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PM – Step 2

"5 x Why": Hydraulic pressure

<u>Problem</u>: Mach. is waiting for signal spindle-unclamping

when unclamping the tool from the spindle: time-out.

hydraulic pressure is 121bar, pressureswitch set on 120bar

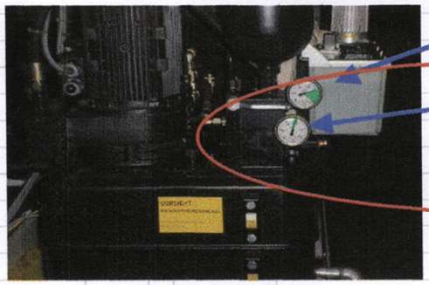
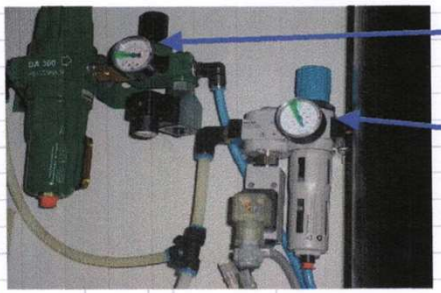
some time is needed to unclamp the tool => time-out.

<u>Action taken</u>: set the hydraulic pressure to 125 bar + green zone on pressure-guage to check by operators.

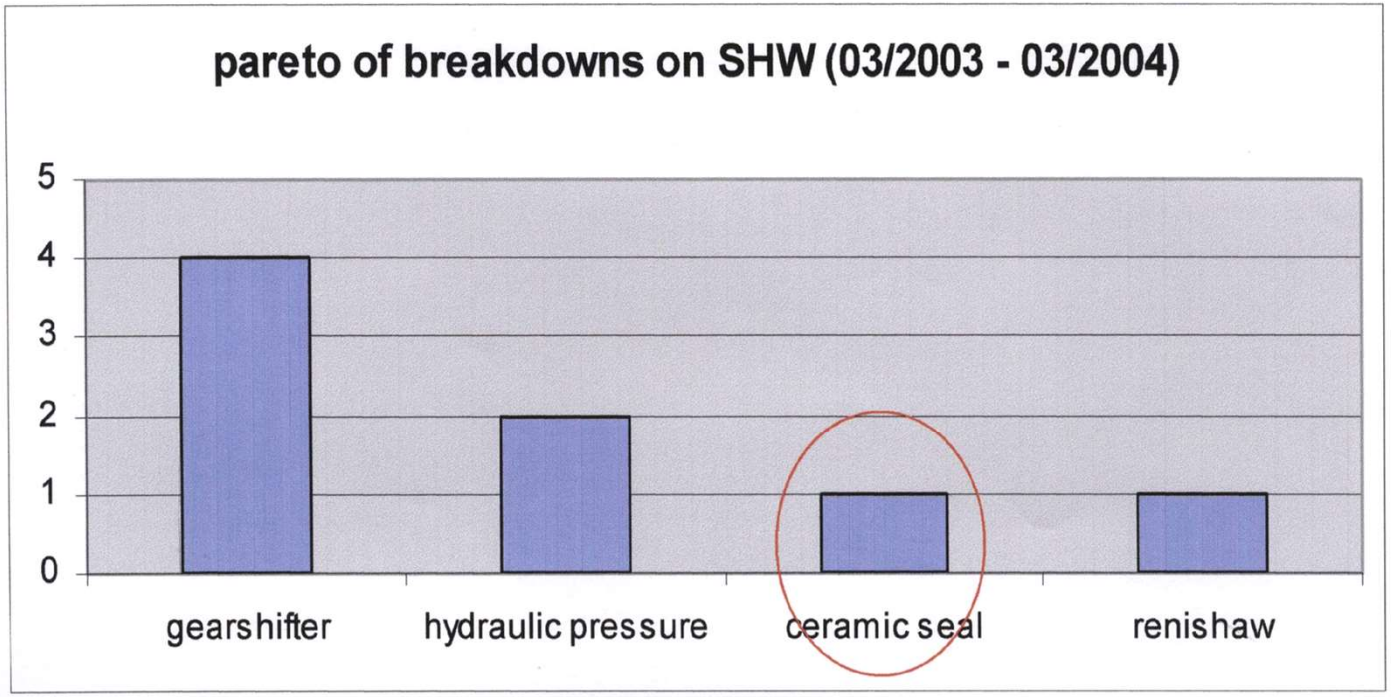
Dagelijks onderhoud

PICANOL | W3914 SHW UFZ 6/L

Stap	Onderdeel	Planning
De grote kuis 1	6.Periodiek kuisplan	wekelijks in V.P.

	Beschrijving	Middelen	Tijd
druk en oliepeil	**1) Drukkontrole hydrauliekgroep** 	**180 Bar** ***gewichtscompensatie*** In het groen gebied **tussen 125-142 Bar** ***Systeem druk*** In het groen gebied	
	2) Persluchtdruk 	**0,9 Bar** ***Meetsystemen*** In het groen gebied **Min. 6 Bar** ***Persluchtdruk*** In het groen gebied	

PM – Step 2
Breakdown analysis



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PM – Step 2

"5 x Why": ceramic rotory seal

Problem: Coolingliquid contaminates gearbox-oil.

coolingliquid escapes through ceramic seal.

ceramic seal is worn out (MTBF: 2 months).

a rotating and a static piece are contstantly rubbing against eachother.

rotating en static ceramic pieces are jointed with a spring.

Action taken: re-design: jointing only when coolingliquid is applied.

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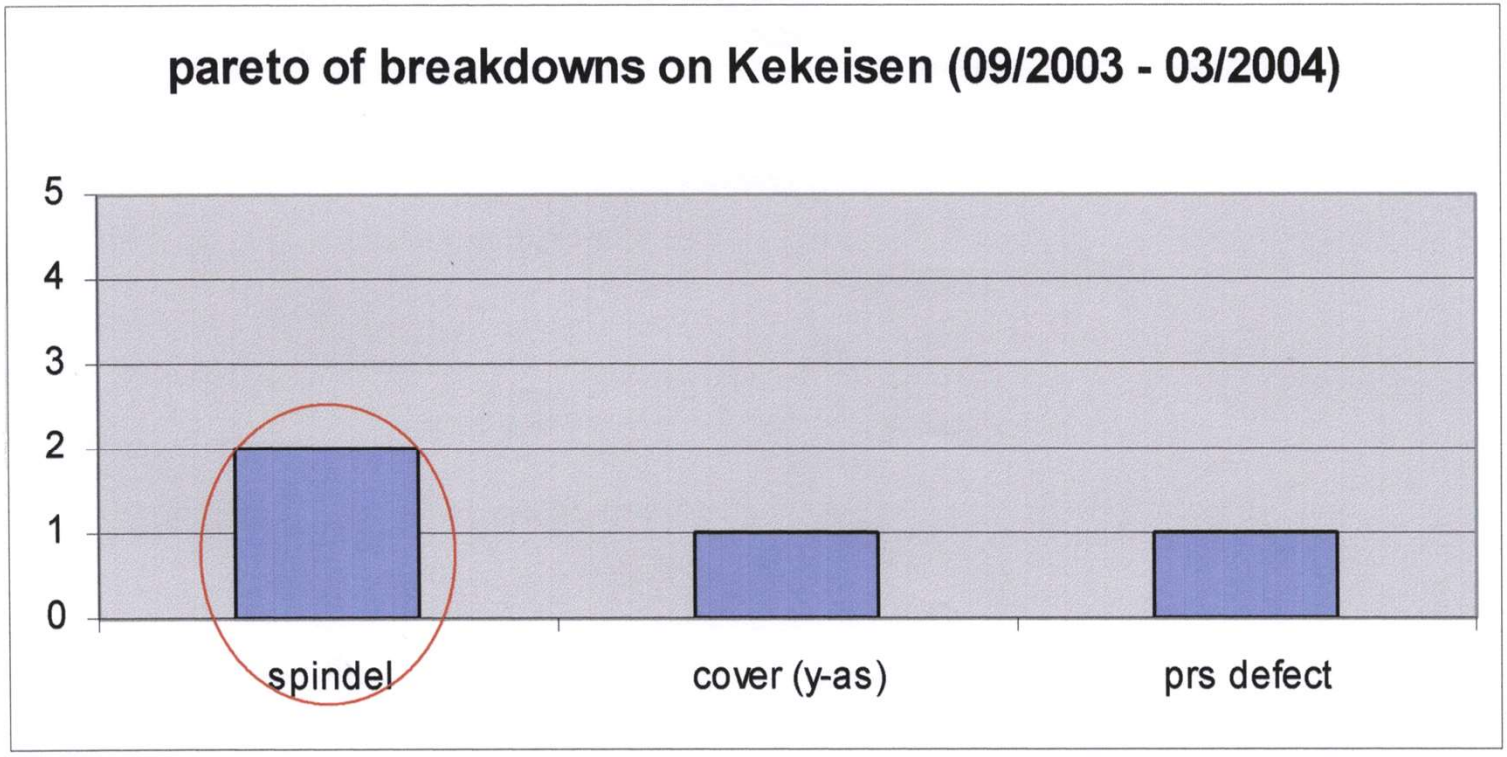
PM – Step 2
Breakdown analysis



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PM – Step 2

"5 x Why": spindlebearings

<u>Problem</u>: Teeth of plastic gear gone.

- overload of theet on plastic gear.
- axis can't rotate easily.
- bearing are running hot at high speeds.
- type of bearing is inappropiate.

<u>Action taken:</u> re-design: mounting of high precision bearings (spindlebearings).

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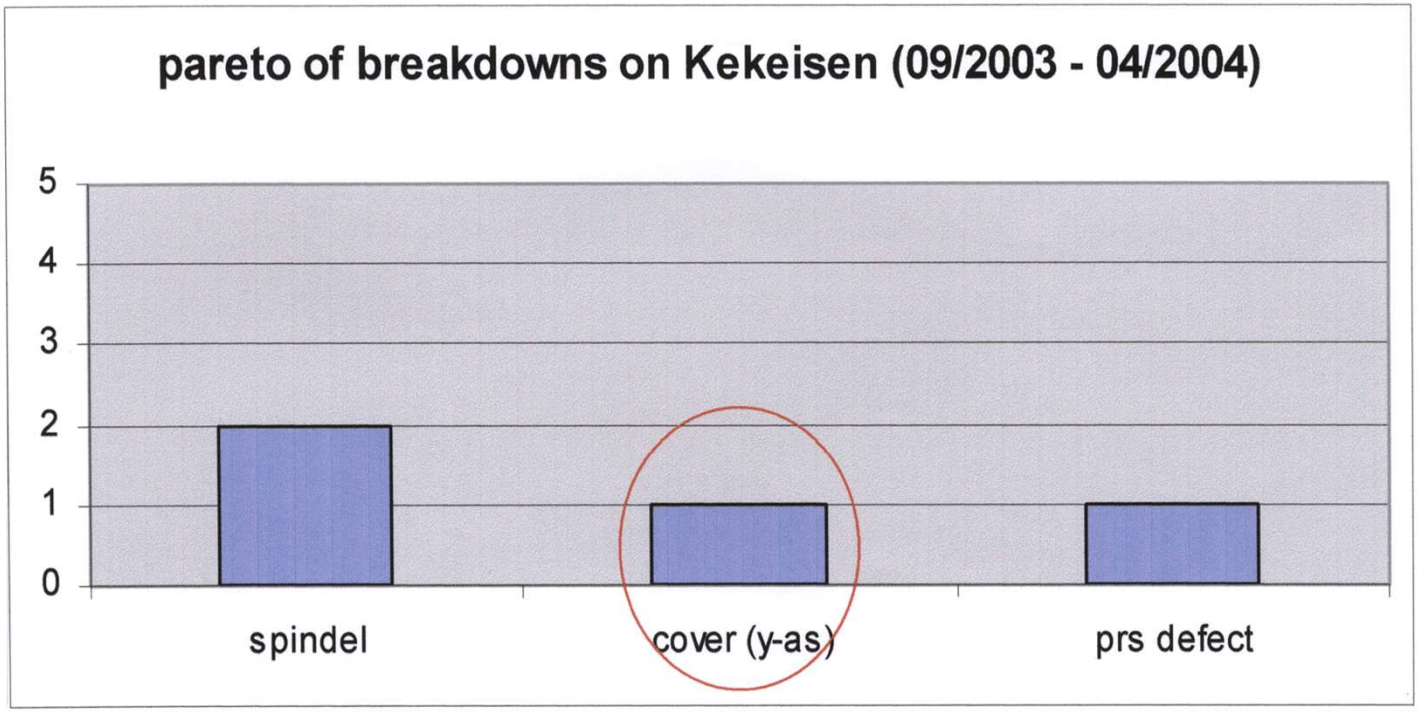
PM – Step 2
Breakdown analysis



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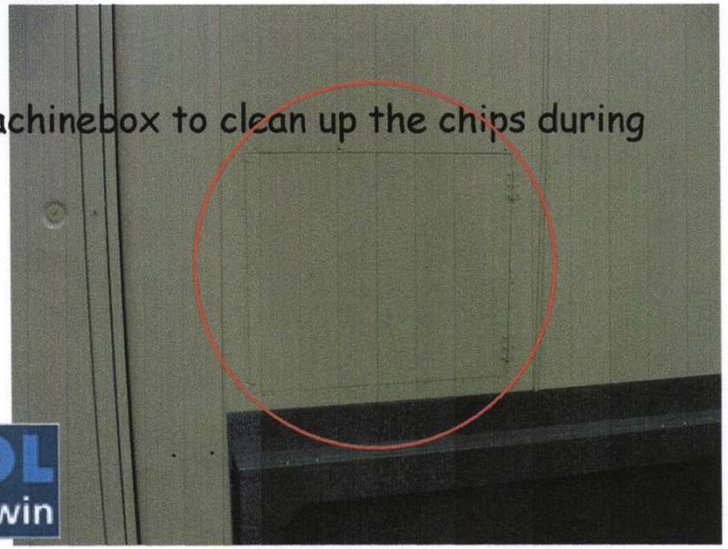
PM – Step 2

"5 x Why": Covers

Problem: Cover damaged.

- cover doesn't roll up.
- rolling up is obstructed due to chips.
- gattering of chips under the cover.

Action taken: the making of doors in the machinebox to clean up the chips during A.M.



Dagelijks onderhoud

PICANOL | Kekeisen

Stap	Onderdeel	Planning
De grote kuis 1	6.Periodiek kuisplan	Wekelijks

K 2	Beschrijving	Middelen	Tijd
VP	Binnenkant spaanvrij maken Blindages controle X Y Z-as	Trekveren controle op breuk,direct melden Blindages achterkant X-as	

PM – Step 3

Establish maintenance standards

In 7 stappen naar **Planmatig onderhoud**

Stap	Doelstelling	Activiteit
vastleggen voor-komingsmaatregelen 3	Oplossingen ter voorkoming van de meest voorkomende oorzaken bepalen	Stel oplossingen voor.

Hoe systematisch en effi

3.1.stel oplossingen voor

Step 3

- map out **maintenance plan** ;

- update installation **standards** ;

- make periodical maintenance interventions **efficient**.

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S-Nr.	Description	#	Unit	ABC - class.	Type of Maintenance
	X-as				
	1. X-AS				
	1.1 AANDRIJVING				
S0068424	SIEM 1FT6105-8AF71-3AG0	1	S	A	BM
S0068589	ZAHNSCHEIBE040100009A33	1	S	B	BM
S0068632	~~ZAHNSCHEIBE 040090003A33~~	~~1~~	~~S~~	~~B~~	BM
S0068633	ZAHNRIEM GT-8M-800-36	1	S	A	TBM
S0068590	~~TLK 300.4203.038.001~~	~~3~~	~~S~~	~~C~~	BM

Planning preventief onderhoud SHW UFZ6

Preventief-module **P-riemen+ketting**

Riemen assen + ketting tegengewicht

Benodigde tijd **180 min.** mechanieker

Nr.	Akties	Aanwijzingen	Middelen
1	Nazicht van tandriemen X-as Y-as Z-as(2x)		Riem X-as: S0068009
			Riem Y-as: S0068457
			Riem Z-as: S0068456
2	Nazicht slijtage Ketting tegengewicht	Toelaatbare verlenging door sleet mag	Ketting: S0068506
		max. 3% bedragen.	
	Wanneer men een lengte meet van 431 mm	Kettingverdeling bedraagt 1 1/2"(38,1mm)	
	over 11 schakels is deze aan vervanging toe	lengte over 11 schakels = 419 mm	
	Op verschillende plaatsen meten.	lengte over 12 schakels = 431 mm	
3	Controle van blaasvoorspandruk stikstofvat tegengewicht	Deze moet 165 bar zijn	
		Hydauliekdruk = 0 bar.	
4	Controle blaasvoorspandruk stikstofvat hydrauliek	Deze moet 60 bar zijn	
5	Hydraulische leidingen en koppelingen nazien	Controleren op oliedichtheid.	

Picanol

Frequency:
2x per year

PM – Step 3

Establish maintenance standards

Preventief-module **P-smering**	**Preventief Controle Centrale Smering** 6 maandelijks	Benodigde Tijd **120 min** Smeerder

Aktie 1

Karter 1 nazien Vetsmering bijvullen
Inhoud 1,8l
Produkt Ossagol V00 **S0067650**

Karter1 vetsmering

Aktie 2 **Shellstaalnamernr 00197052**

Karter 2 nazien Spindelkarter aflaten
Inhoud 60 liter
Produkt Morlina 10 **S0054572**
Filter Mahle OC17(**S0063490**
Vervangen

Filter Mahle OC 170

Onder koeler Spindelkarter 2

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Step 1: Elimination and prevention of deterioration

1.1. Equipment Ledger: see book.

1.2. Evaluation of equipment.

1.3. Failure rank defining.

1.4. Grasp of present status (ABC, MTBF,...)

1.5. Maintenance goals.

1.6. Support A.M.-activities

→ **Expanded B.O.M.**

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B/D-analysis (5x why): Palletchanger

→ **<u>Problem</u>: palletchanger put pallet through closed door**

Door got loose of pneumatic cylinder

Bolts out.

Detection "door open/close" is on pneum. cylinder

New detection on door itself.

Fix bolts with glue.

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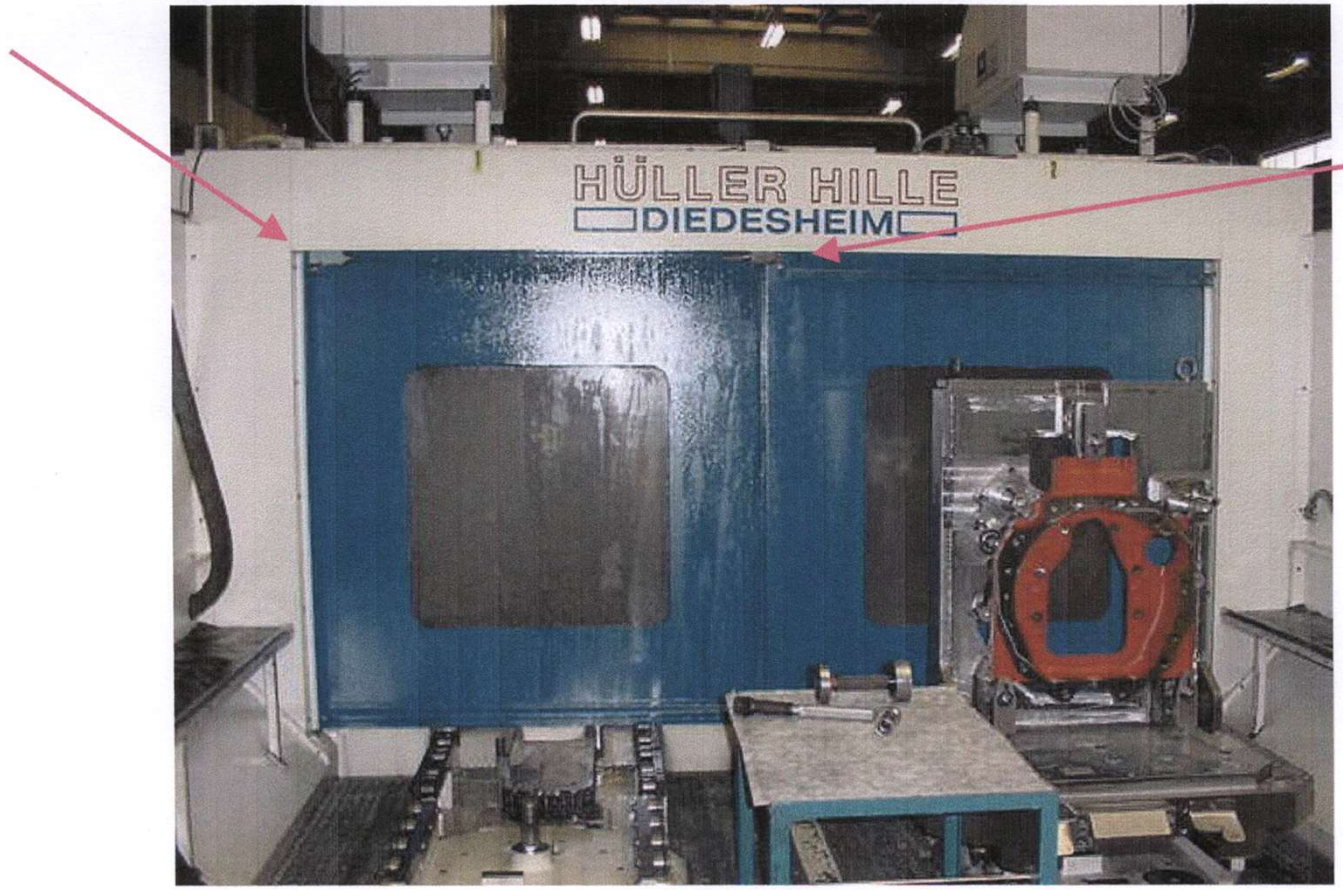
Palletdoors



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➢ B/D-analysis (5x why): Palletchanger

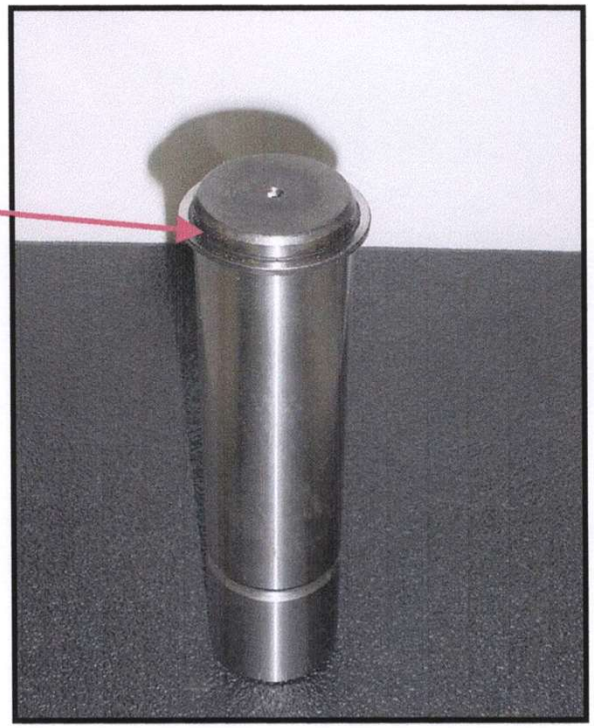
→ **<u>Problem</u>: No indication "pallet blocked"**

Fixationpin to high.

Fixationpin broken

Material pin to hard

New pin in soft material



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➢B/D-analysis (5x why): Toolchanger

→ **<u>Problem</u>: Changer don't take a loaded tool**

PLC is waiting for a replaced tool in the pocket

Dirt activates the proximity switch

Proximity switch detects nothing

Indiation with LED's on the connectioncable

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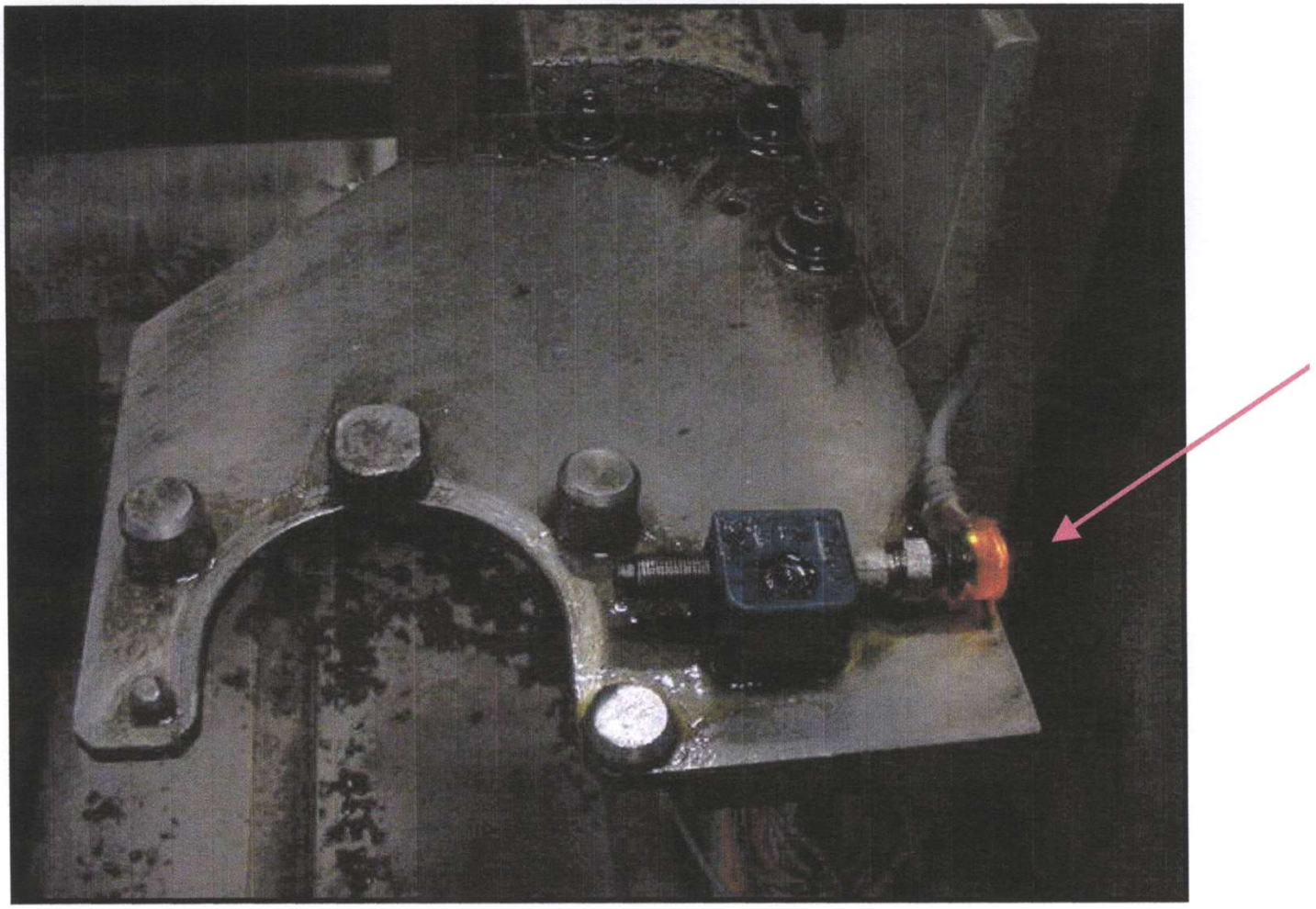

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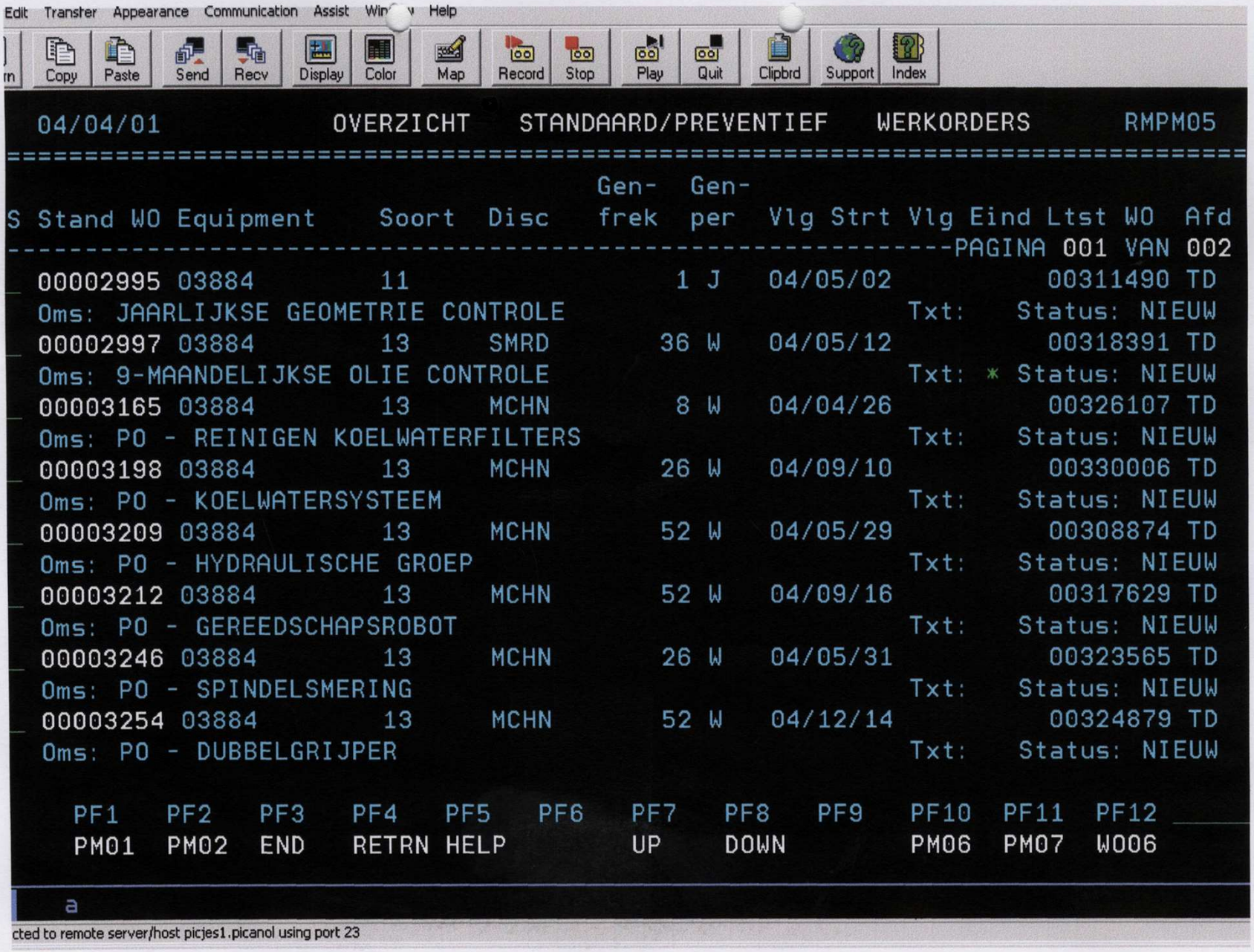
Step 3: Establishment of maintenance standards

1. Combination supplier instructions & own experience.
2. Result of analysis breakdowns.
3. Result of BOM/Ledger
4. Analysis failure modes, effects & consequenses.
5. Refining of the existing PM.
   => contents
   => frequency
   => worktime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Oms: PO - DUBBELGRIJPER Txt: Status: NIEUW
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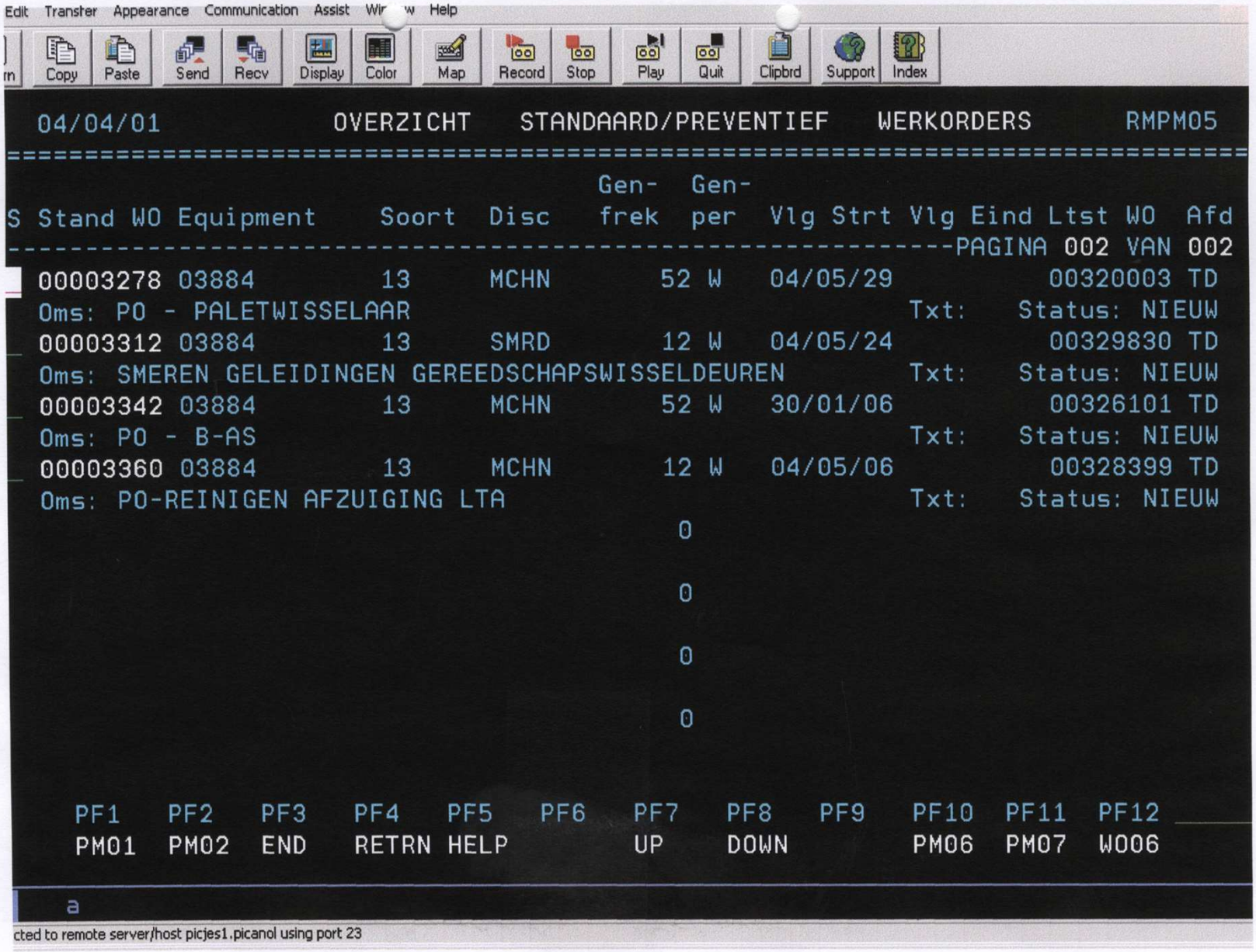
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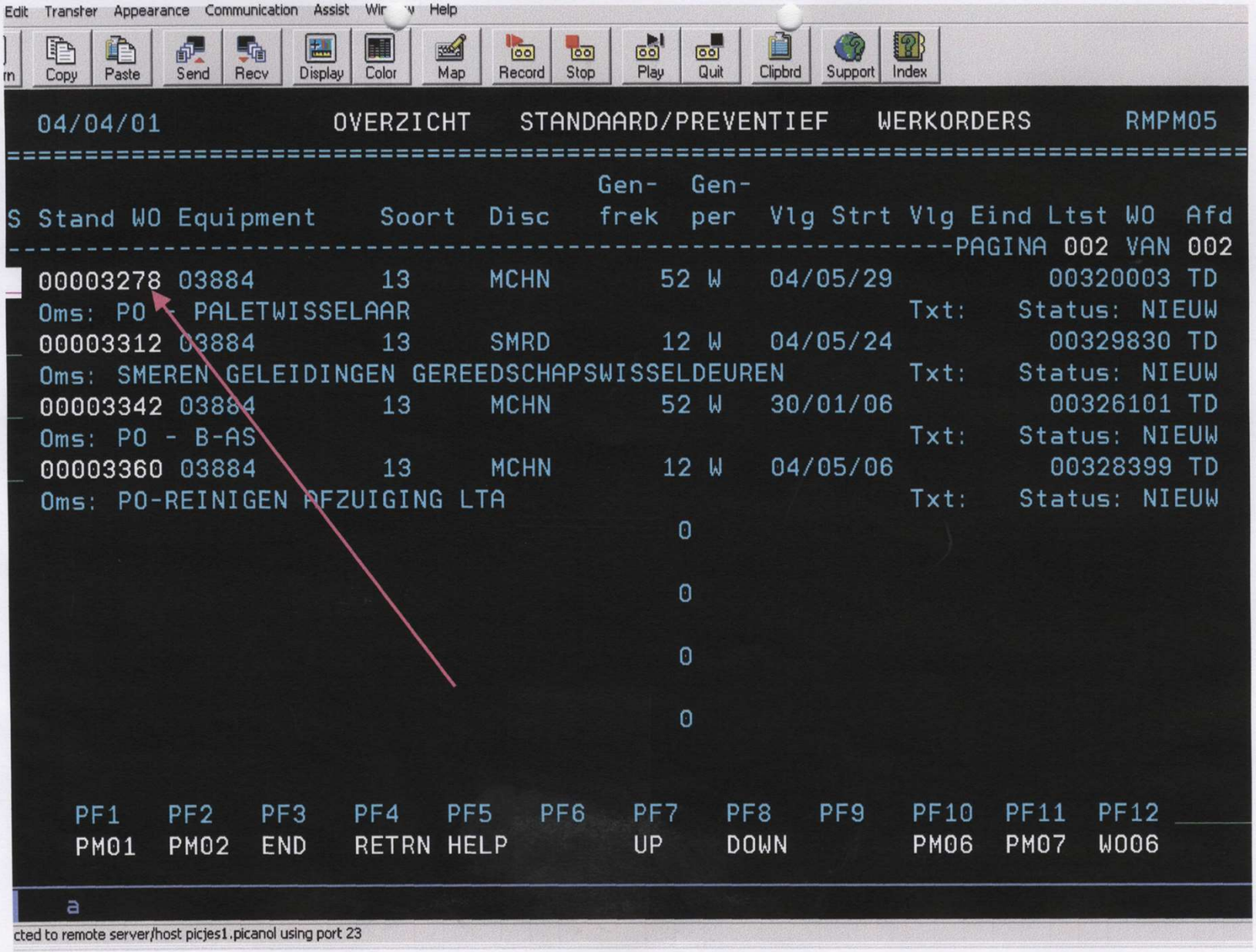
Palletdoors

S-Nr.	Description	#	Unit	ABC - class.	Type of Maintenance	Part-history				
						Initial failure	chance failure	wear failure	MTBF / deviation (cal.days)	MTTR / deviation (hours)
	6.5. PALETWISSELDEUREN									
S0066076	PARKER VQB22-Q-0-5-G1/4B	2	S	B	BM	0	0	1	1088/0	6/0
S0066599	FESTO DGP-40-2000-PPV-A-B	2	S	A	BM					
S0068015	NMG 105 8X25	2	S	C	BM					
S0068627	FESTO DICHTINGSSET DPG40	2	S	C	BM	0	0	1	1088/0	6/0

PM

Add to PM 3278 Palletchanger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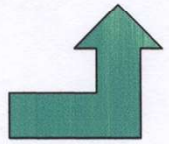
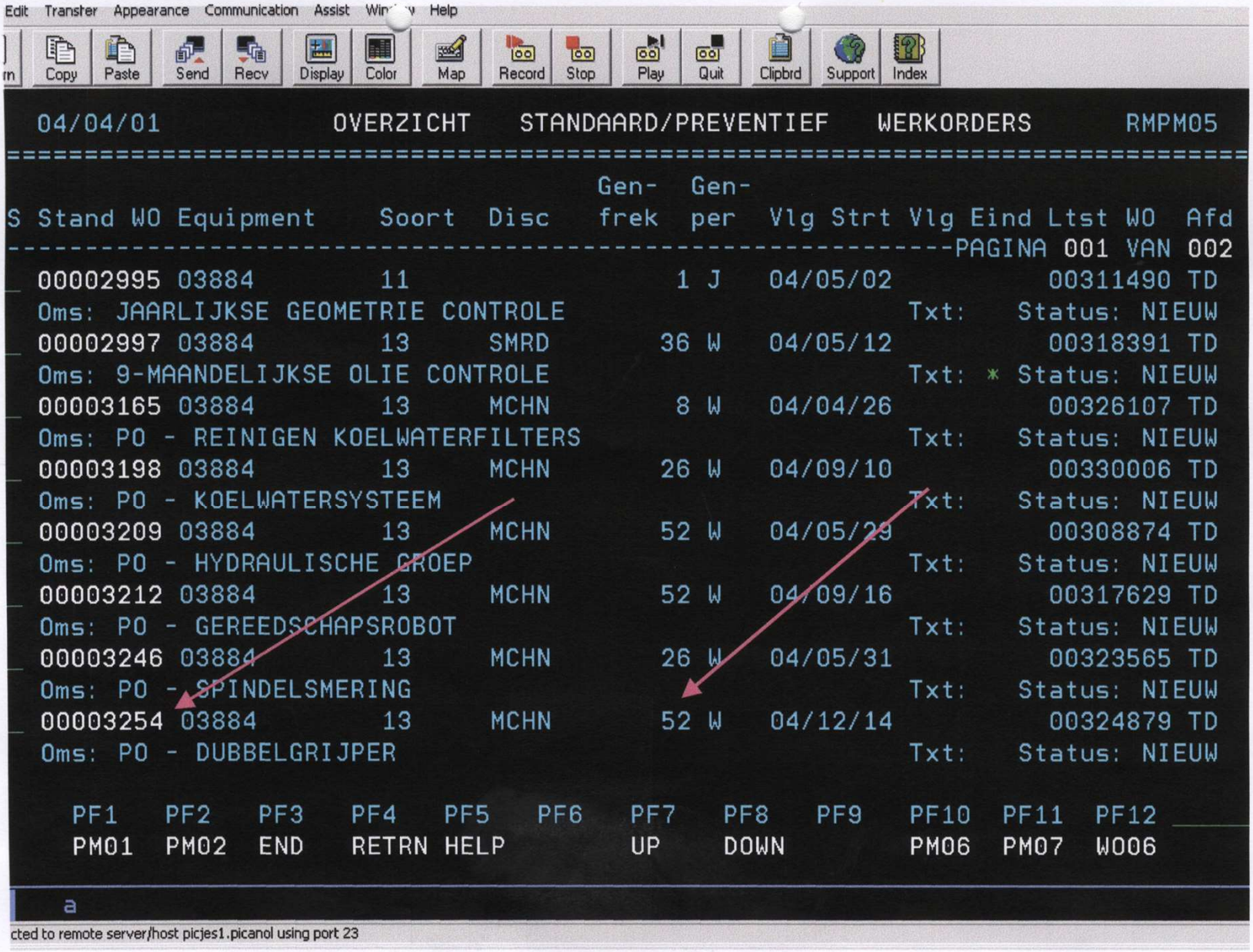
Toolchanger

S-Nr.	Description	#	Unit	ABC - class.	Type of Maintenance	Part-history				
						Initial failure	chance failure	wear failure	MTBF / deviation (cal.days)	MTTR / deviation (hours)
	7.3. GEREEDSCHAPSKLEMMING									
S0065631	O-RING 34 X 2 NBR 36642	4	S	B	TBM	1	0	1	172/386	4/0
S0065632	STEPSEAL K PS1600300-Z51N	4	S	B	TBM					
S0065633	WYNSEAL PW41 0 380-WUAQ3	2	S	B	TBM					
S0052614	HÜLLER DRUCKFEDER2X16X145	2	S	A	TBM	1	0	1	172/386	4/0



Change frequenty PM 3254 toolchanger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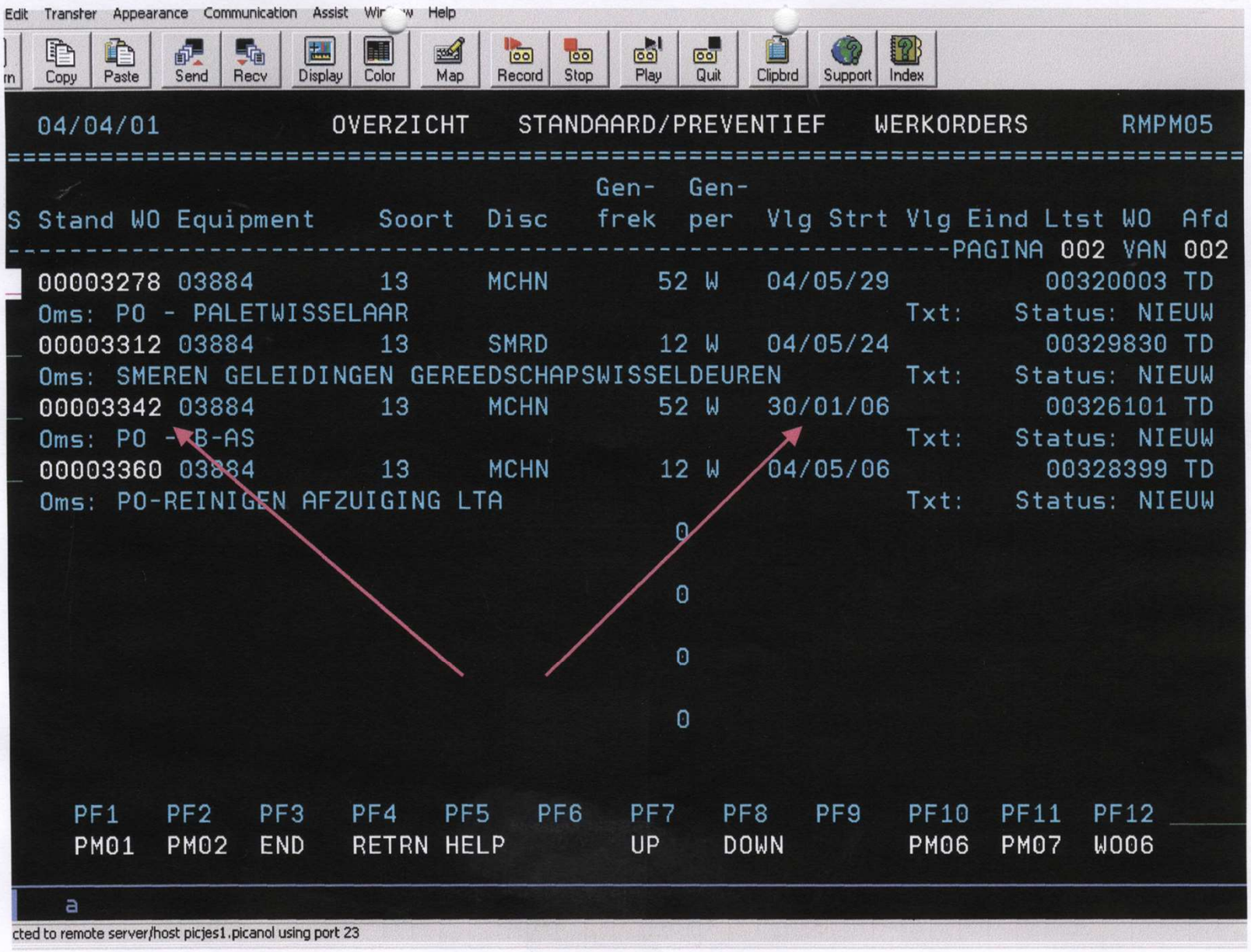
B-axis

S-Nr.	Description	#	Unit	ABC - class.	Type of Maintenance	Part-history				
						Initial failure	chance failure	wear failure	MTBF / deviation (cal.days)	MTTR / deviation (hours)
	2. DRAAITAFEL (B-AS)									
	2.1. AANDRIJVING NC-TAFEL									
S0063968	SIEM. 1FT6102-1AC71-4AG1	1	S	A	BM					
S0064022	HEIDENHAIN ROD780C 18000P	1	S	A	BM					
S0065828	GERWAH KOPP.AKN 150-38-32	1	S	A	TBM					
S0063651	TURCON ROTO GLYD-RING	6	S	A	TBM					
S0063652	O-RING 132 X 3 88NBR156	1	S	B	TBM					
S0063685	O-RING 100 X 5 88NBR156	1	S	B	TBM					
S0063730	DICHTRING DIN 07603	4	S	C	TBM					
S 34453	OLIEKEERR. 52 X 68 X 8 R	1	S	C	TBM					
S 20219	OLIEKEERR. BA 35X47X7	1	S	C	TBM					
S0064090	CU RONDSEL 55 X 48 X 2	2	S	C	TBM					

BM

Delete PM 3342 B-axis

21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Analysis existing PM: how?

- Is the part still doing what we want it to do?
  => lower frequency.
- Is the part abnormaly contaminated?
  => redesign.
- Possibility to eliminate PM on parts by redesign?
- Possibility to add checkpoints on the machine?
- Short daily contact with operators & tech.people.

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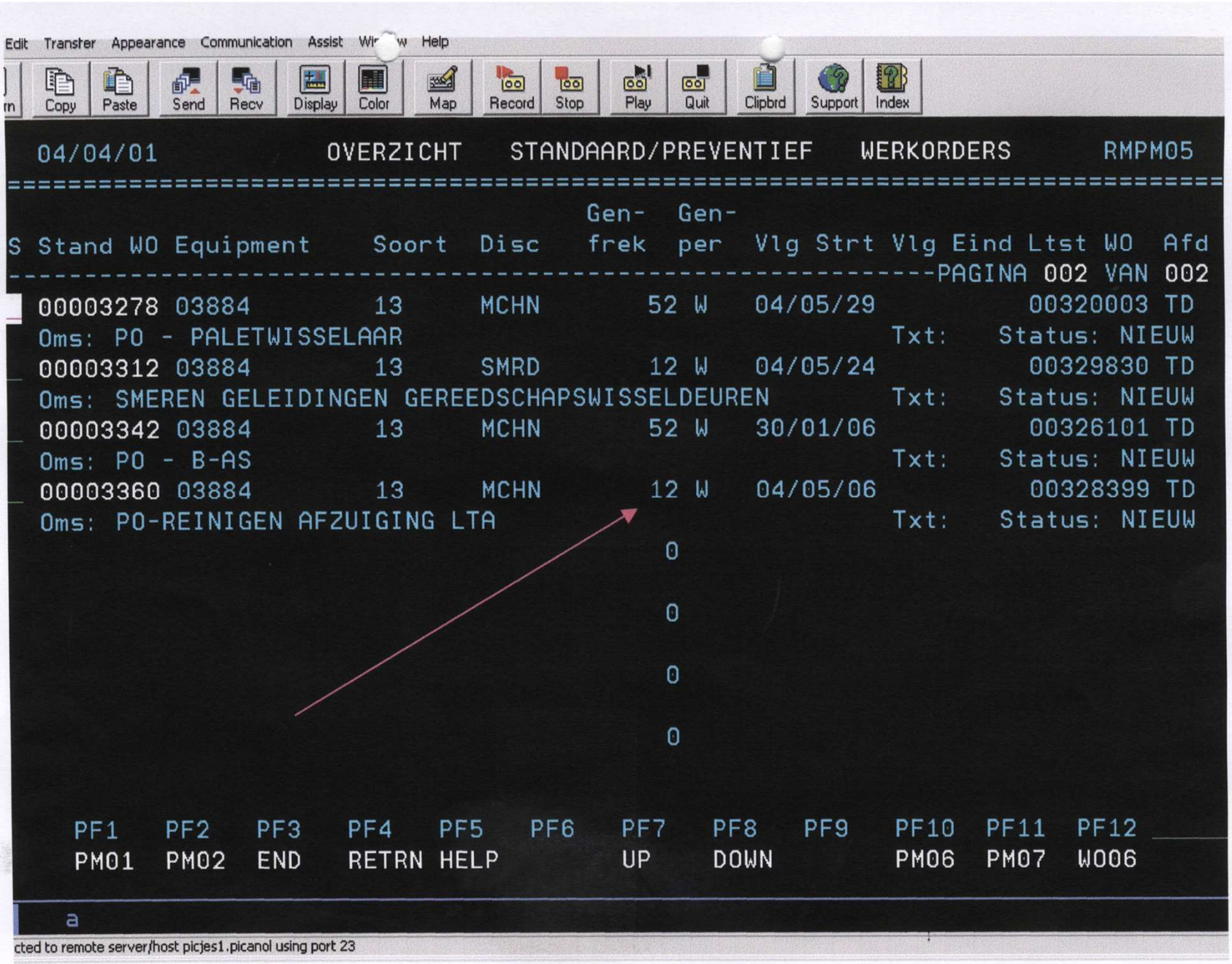
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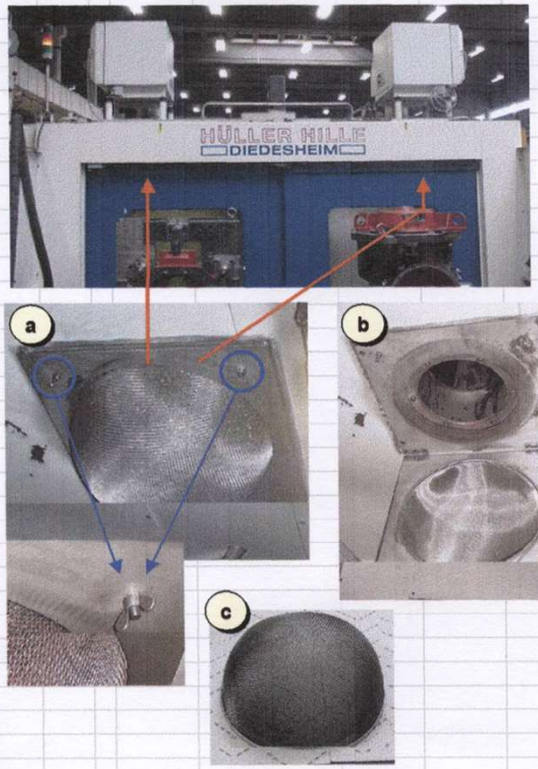
Stap	Onderdeel	Planning
De grote kuis 1	6.Periodiek kuisplan	MAANDELIJKS

K4	Beschrijving	Middelen	Tijd
B	***Reinigen van LTA - afzuiging***  a. Demonteer de filter dmv. de 2 vleugelmoeren. b. Neem filternet uit c. Verwijder alle spanen uit de filter, spoel filter uit en monteer deze terug		

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Water filtration

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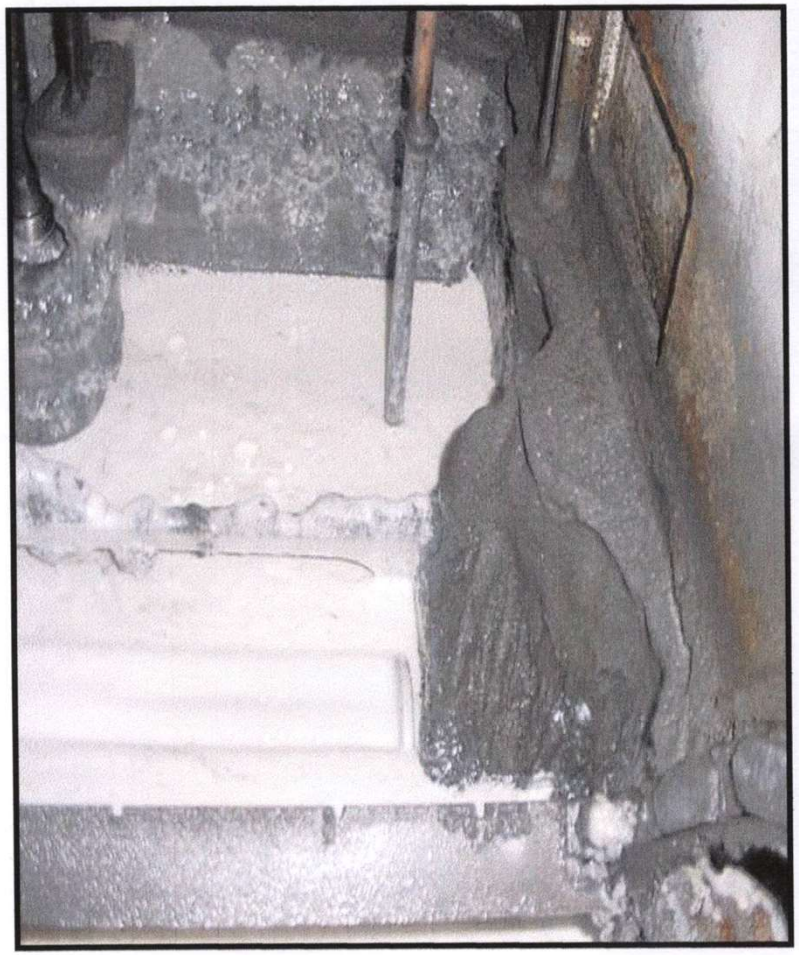

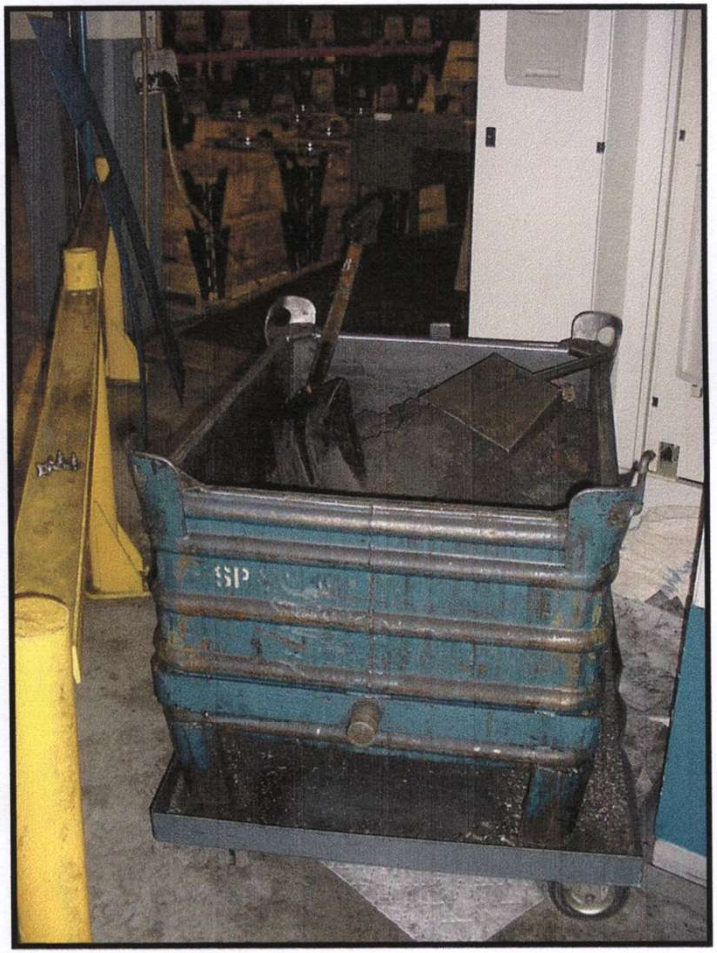

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Water filtration

=> Result: pictures: 3 months.

=> PM every half a year = insufficiënt.

=> Consequences of dirty water:

* breakdowns Deublin parts & extreme wear pumps.
* change filters with high frequency.
* dirty workpieces & machine

=> action: reduce # tools working without water.

=> redesign: ??

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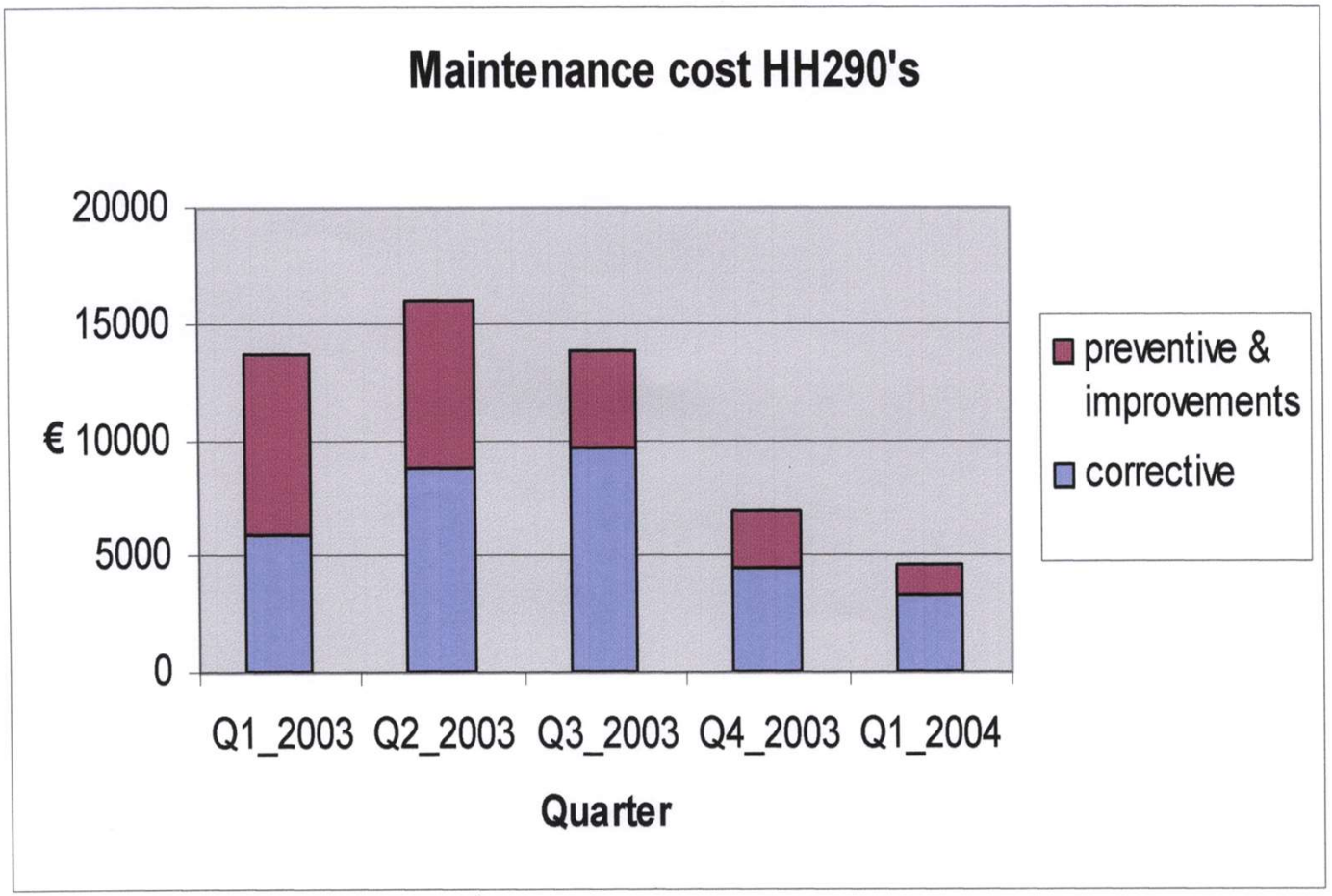


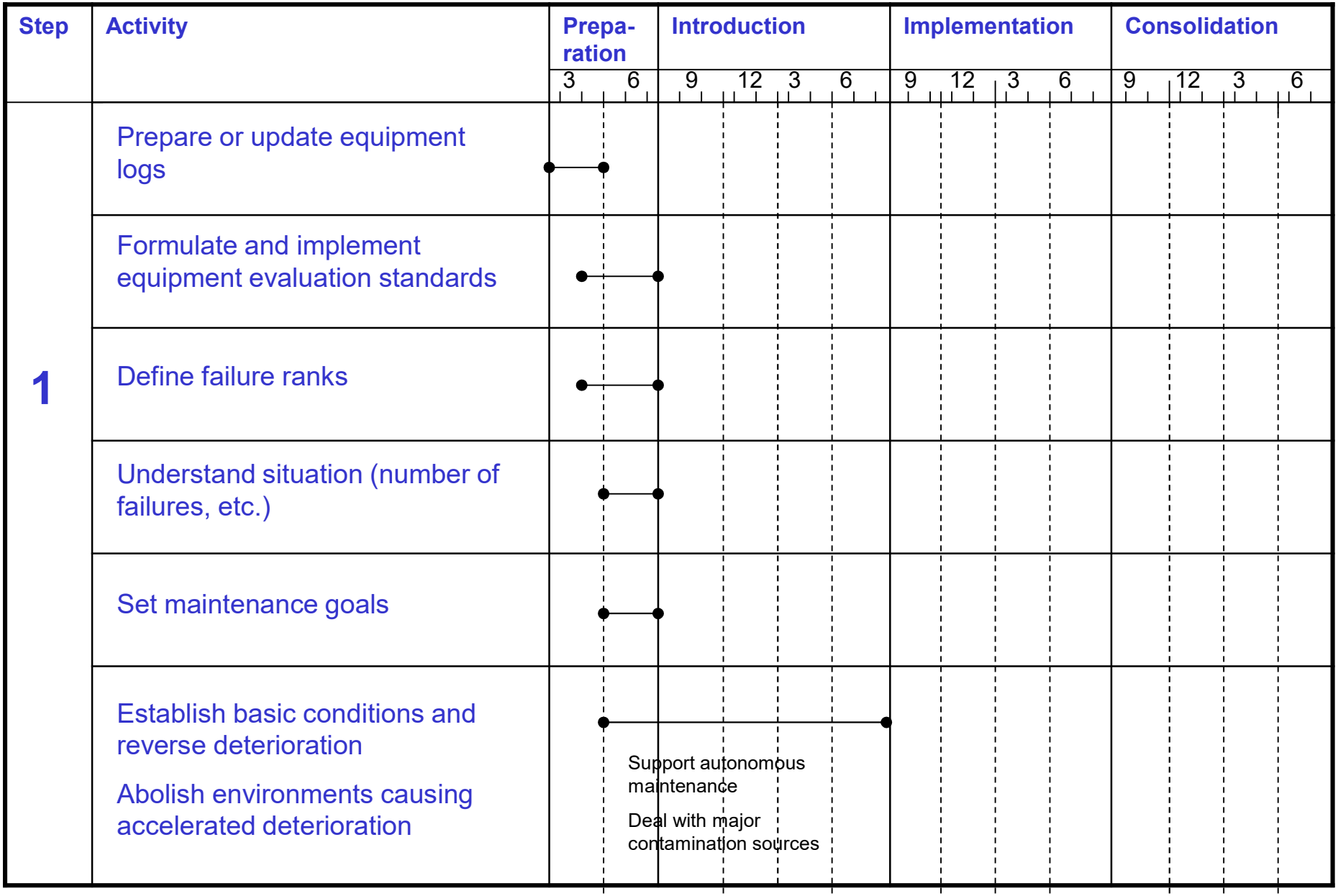
Kinds of Maintenance Records and Purpose of Utilization

	Categories of function	Record name	Contents	Purpose of utilization	In charge	Remarks
1	Activities to prevent deterioration of equipment	Daily inspection check sheet	This is the appearance inspection of equipment which is necessary for operation. Irregularities should be checked for everyday	Disposal of the discovered abnormality and a report to the head and the maintenance division	Line operator	It is acceptable that the oil charge record is combined.
2		Oil supply /Oil change record table	Record of oil supply to the places which are necessary for the operation and exchange of deteriorated lubrication	Improvement of oily charge method and lubrication management	Line operator	
3	Activities to measure deterioration of equipment	Periodical inspection record	To measure and record the situation of deterioration and abrasion This should be made based on the necessity.	As a result of the measure, if it was reached to the maximum limit, it should be repaired or fixed.	Person in charge of the maintenance division	Maximum value is described in the inspection standards

	Categories of function	Record name	Contents	Purpose of utilization	In charge	Remarks
4	Activities to recover from deterioration of equipment	Maintenance report	To record the contents of sporadic failure repair, planned and corrective maintenances in detail.	Failure statistics should be recorded and emphasizing management equipment and items should be determined.	Person in charge of the maintenance division	
5		Corrective maintenance record	The record of plans, execution and the result of corrective maintenance	To promote the standardization of the new method. To correct the causes. To make educational materials for correction samples	Person in charge or staff of maintenance and equipment design division	It is desirable to do this for equipment of a similar type
6		MTBF analysis record table	To record all maintenance work such as repairs for sporadic failures, supplying and changing oil, periodical mechanical maintenance, etc.	For the improvement to extend the cycle of maintenance work and to handle efficiently.	Line, or maintenance division, regular or subcontractors.	

	Categories of function	Record name	Contents	Purpose of utilization	In charge	Remarks
7	Life long record of equipment	Equipment ledger	Record of contents and amounts of money for major failure repair, periodical mechanical maintenance and corrective maintenance	By the equipment lifetime costs, renewal is judged or equipment investment is determined.	Person in charge of the maintenance division	Maximum value is described in the inspection standards
8	Maintenance cost budget management	Maintenance cost record	To grasp the maintenance labor cost, material cost and subcontractor cost. To grasp of result by equipment	To grasp the important points of management of maintenance budget or reduction of maintenance costs and to prepare countermeasures.	Person in charge or staff of the maintenance, procurement or purchasing division	It should be understood by the accounting division.

Planned Maintenance Master Plan



Planned Maintenance Master Plan

Step	Activity	Prepa-ration	Introduction			Implementation				Consolidation			
		3	6	9	12	3	6	9	12	3	6	9	12	3	6
2	Take measures to prevent identical or similar major failures from occurring.			Build systems		Evolve activities									
	Introduce improvements to reduce process failures.														

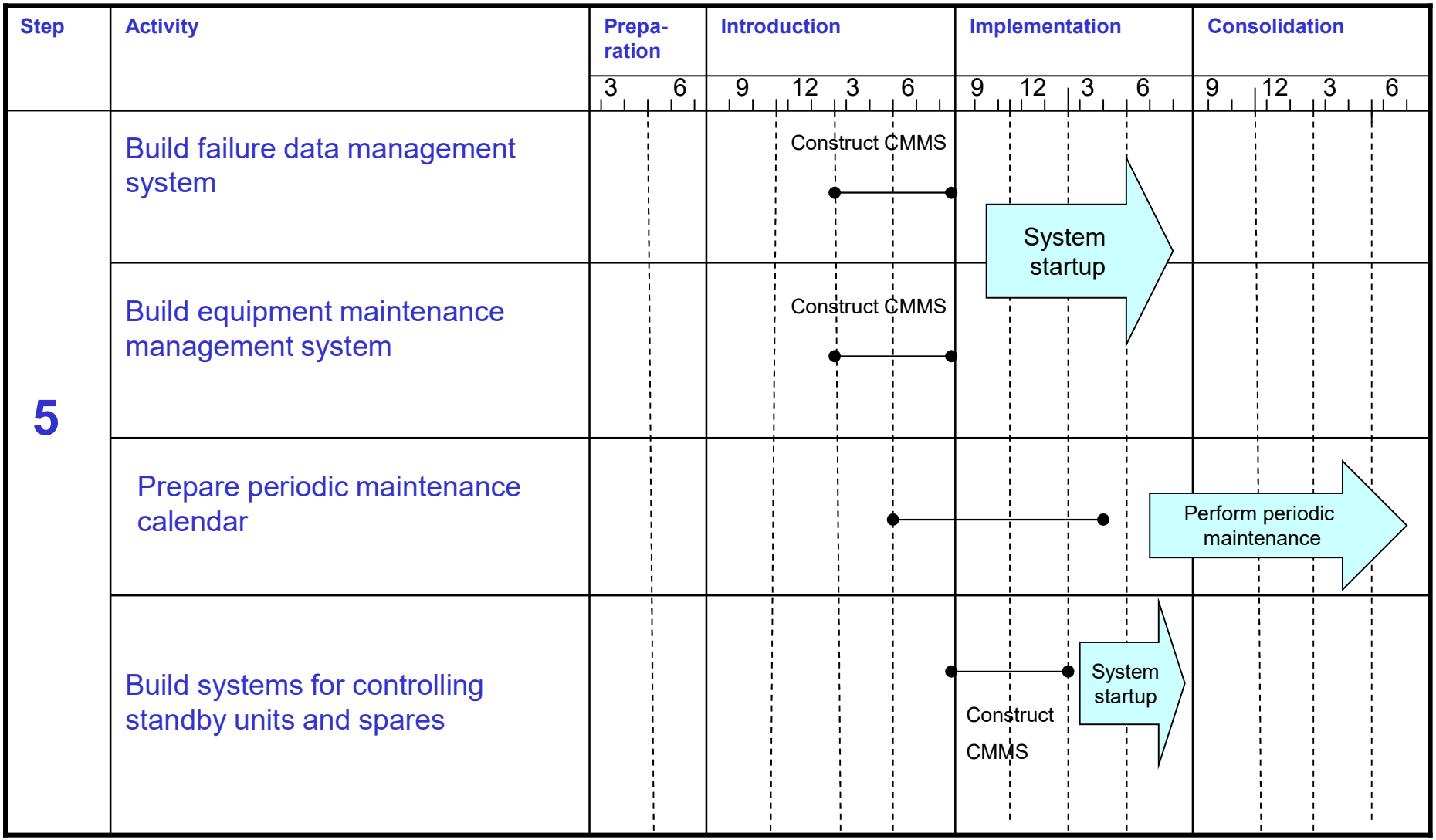
Planned Maintenance Master Plan

Step	Activity	Prepa-ration	Introduction	Implementation	Consolidation
		3 6	9 12 3 6	9 12 3 6	9 12 3 6
3	Prepare for periodic maintenance			Lubricants, spare parts, drawings, etc.	
	Prepare for periodic maintenance worksheets			Design work flow	Perform periodic maintenance
	Select equipment and components for periodic maintenance				
	Reinforce work management (prepare standards)				
	Improve shutdown maintenance efficiency Strengthen control of subcontracted work				

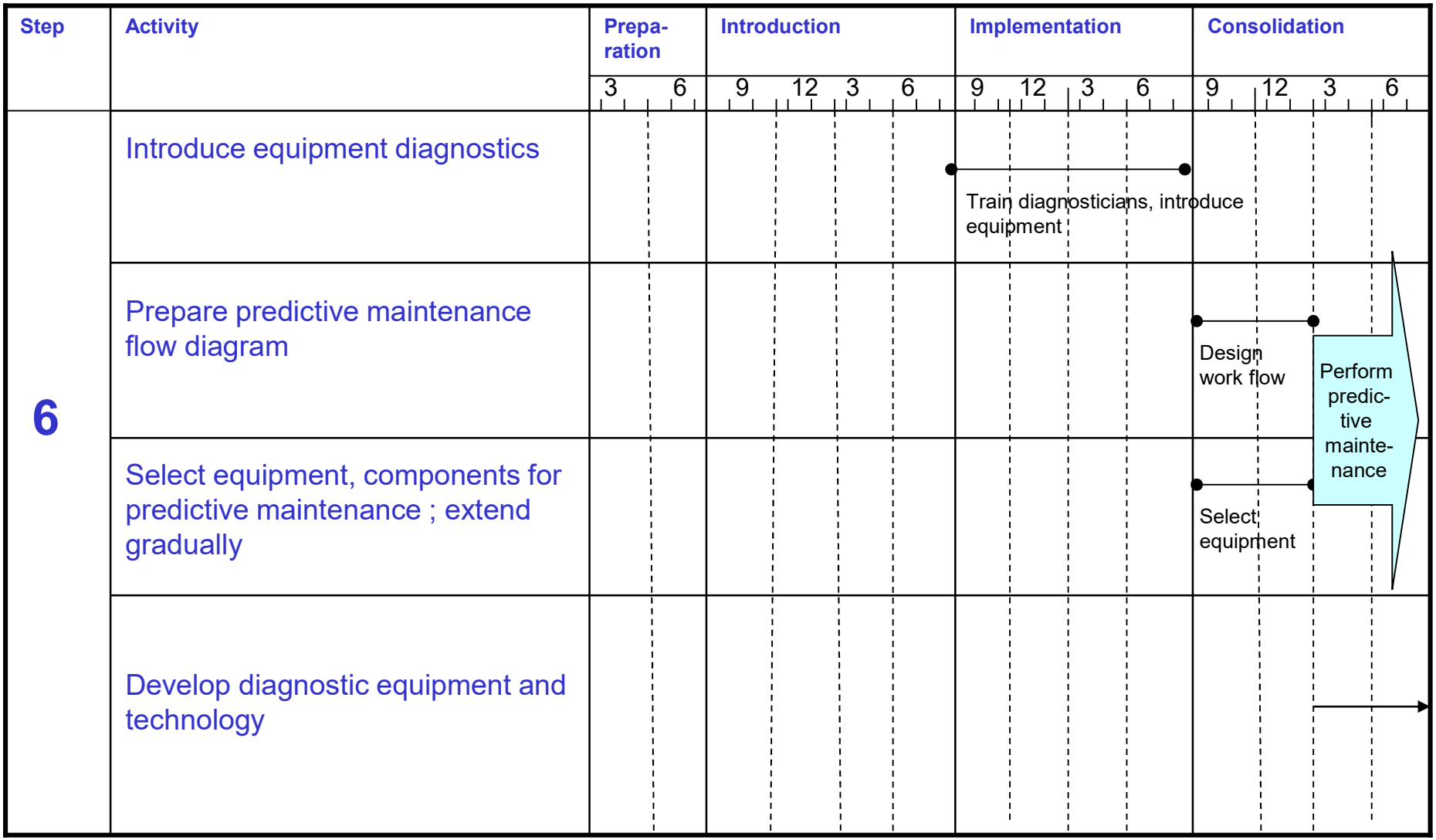
Planned Maintenance Master Plan

Step	Activity	Prepa-ration	Introduction			Implementation				Consolidation			
		3	6	9	12	3	6	9	12	3	6	9	12	3	6
4	Lengthen equipment lifetimes by correcting weaknesses							Corrective mainte-Nance work							

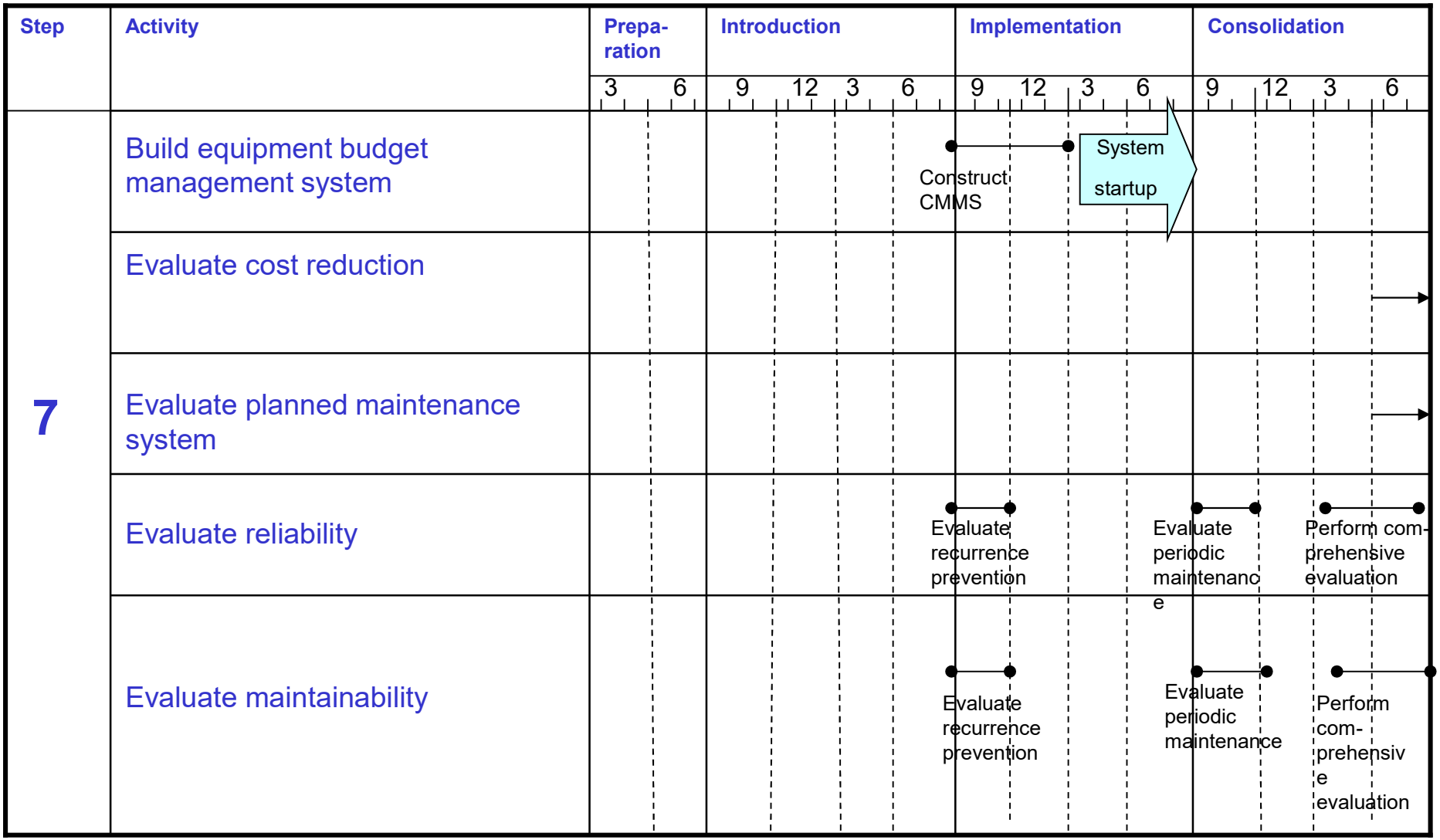
Planned Maintenance Master Plan

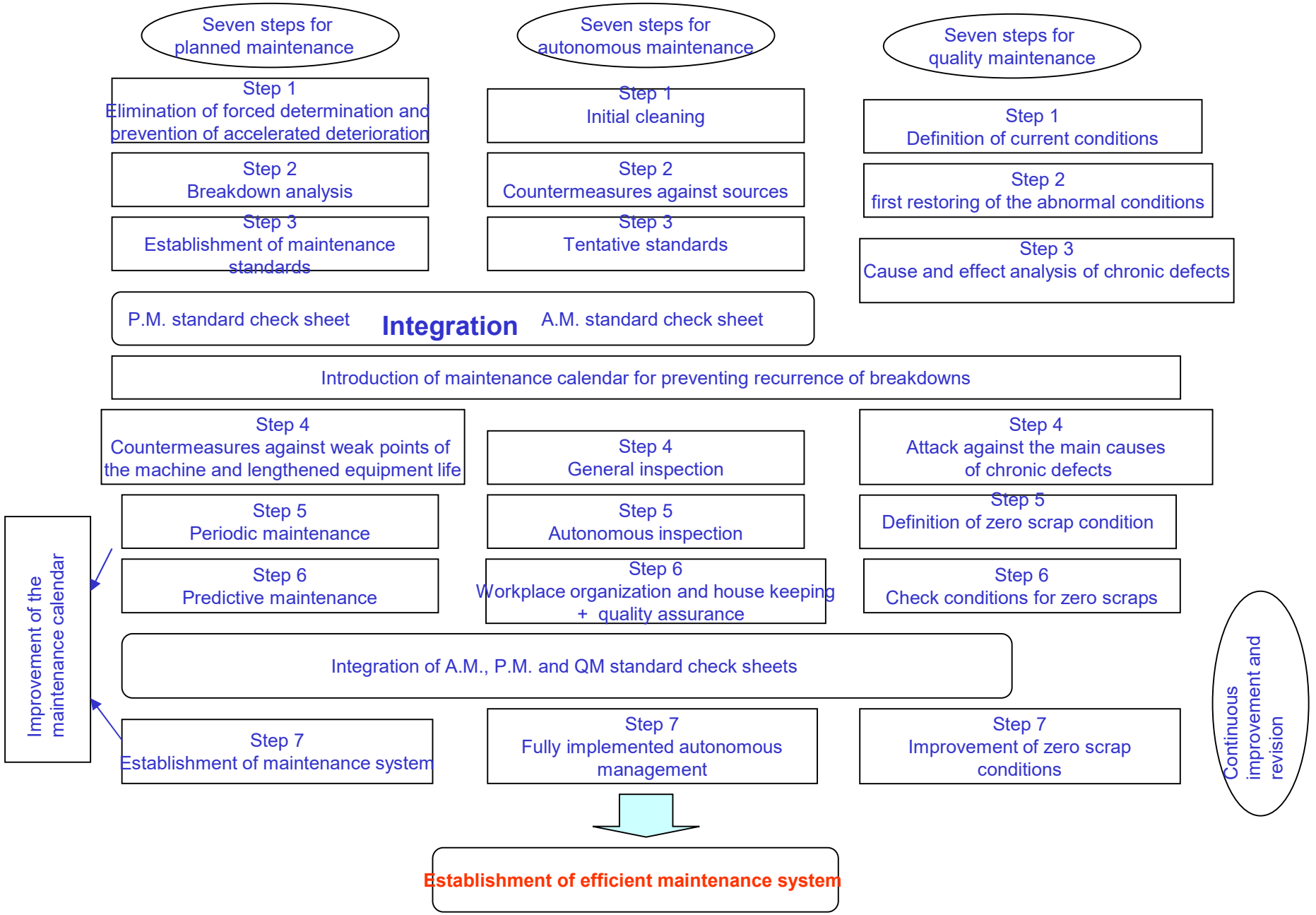


Planned Maintenance Master Plan

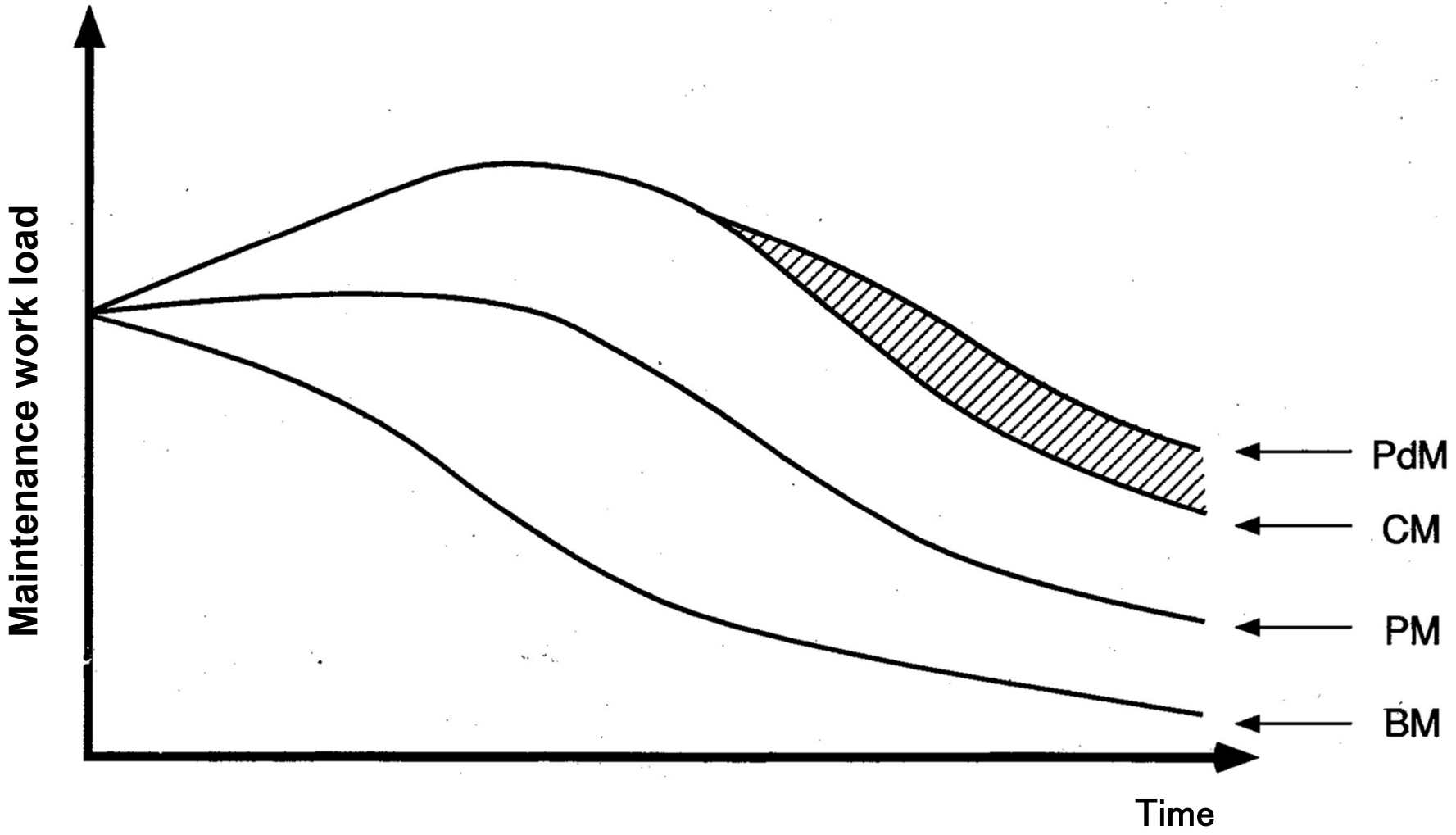


Planned Maintenance Master Plan

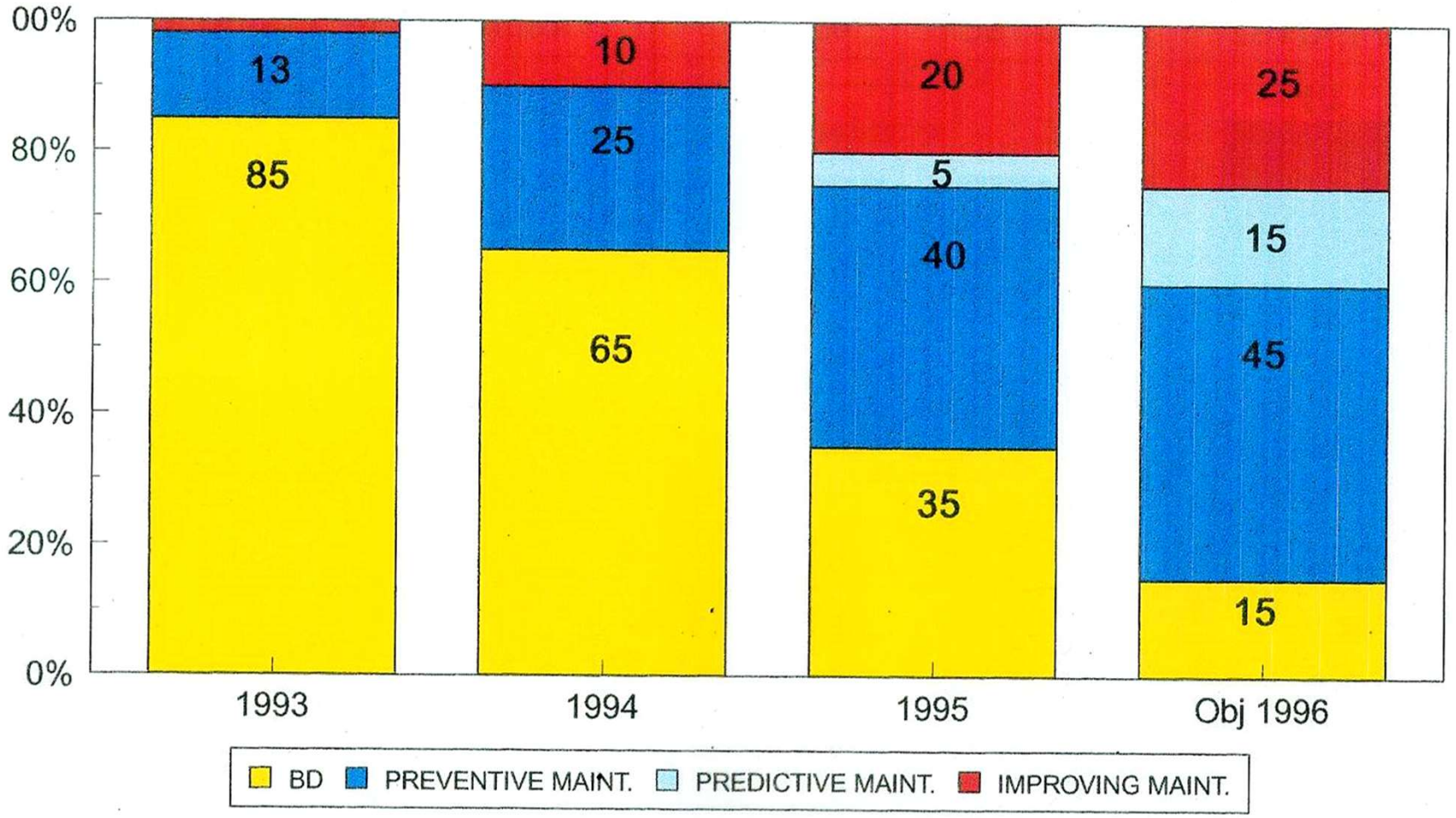



Seven steps for planned maintenance
Seven steps for autonomous maintenance
Seven steps for quality maintenance
Step 1 Elimination of forced determination and prevention of accelerated deterioration
Step 2 Breakdown analysis
Step 3 Establishment of maintenance standards
Step 1 Initial cleaning
Step 2 Countermeasures against sources
Step 3 Tentative standards
Step 1 Definition of current conditions
Step 2 first restoring of the abnormal conditions
Step 3 Cause and effect analysis of chronic defects
P.M. standard check sheet
Integration
A.M. standard check sheet
Introduction of maintenance calendar for preventing recurrence of breakdowns
Step 4 Countermeasures against weak points of the machine and lengthened equipment life
Step 5 Periodic maintenance
Step 6 Predictive maintenance
Step 4 General inspection
Step 5 Autonomous inspection
Step 6 Workplace organization and house keeping + quality assurance
Step 4 Attack against the main causes of chronic defects
Step 5 Definition of zero scrap condition
Step 6 Check conditions for zero scraps
Improvement of the maintenance calendar
Integration of A.M., P.M. and QM standard check sheets
Step 7 Establishment of maintenance system
Step 7 Fully implemented autonomous management
Step 7 Improvement of zero scrap conditions
Continuous improvement and revision
Establishment of efficient maintenance system

Transition of Contents of Maintenance Work

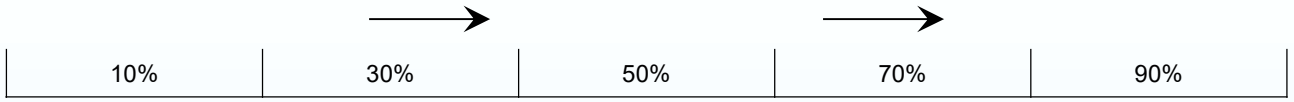
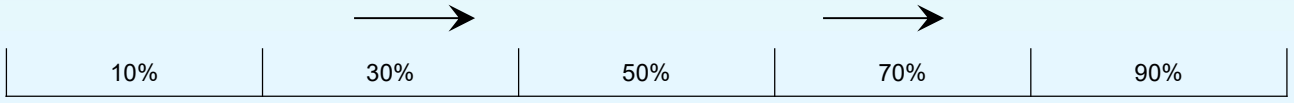


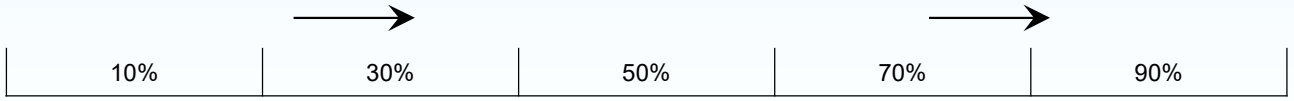
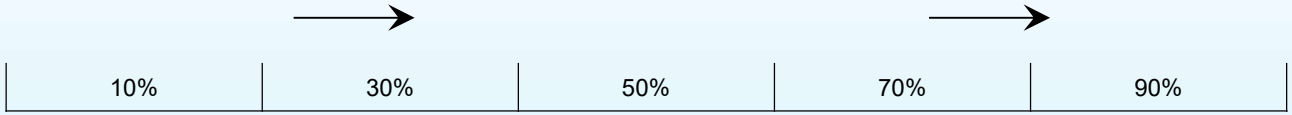
Change of Maintenance



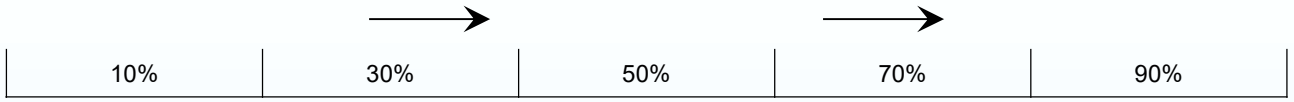
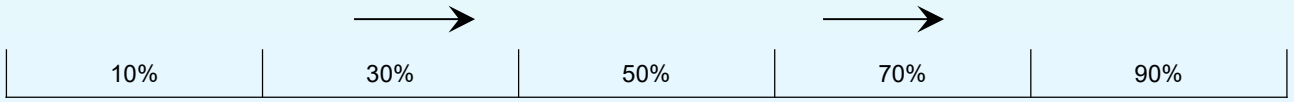
PM Criteria

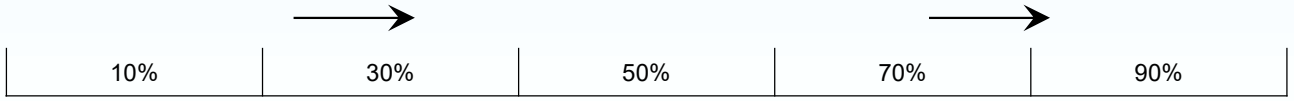
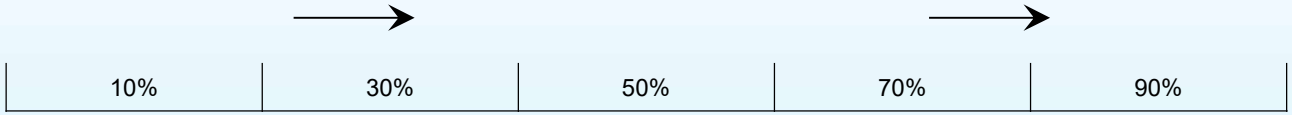
Step 1 :Evaluate equipment, understand situation and eliminate forced deterioration

Level 1	Equipment evaluation standards are not available. Machine ledgers are not available. Lack of understanding situations (OEE, the number of failures, failure severity rate, etc.) Needs of training of maintenance not identified. No control of spare parts stores, obsolete spare parts.
Level 2	Model machines are selected. The equipment situation (OEE, etc.) is well known. Maintenance goals are clearly set. Shutdown maintenance is still carried out ad hoc. 5S in the spare parts stores. 
Level3	Activities to eliminate forced deterioration are taking place together with AM teams. Good results in reducing forced deterioration. 

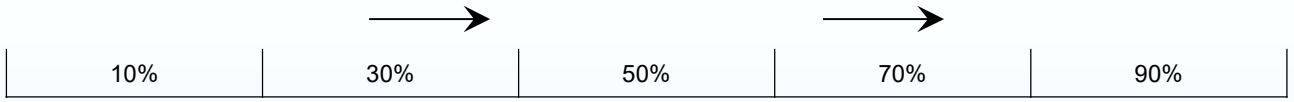
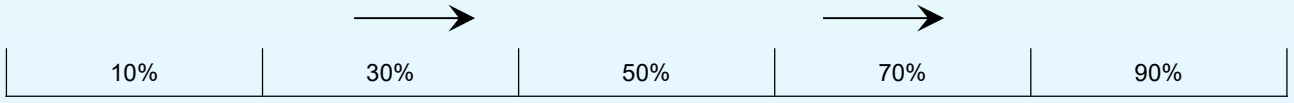
Level 4	Activities to prevent, measure, restore and improve equipment for major machines are carried out with substantial results in reducing failures caused by forced deterioration. 
Level 5	Machine ledgers for major equipment are available. Whether breakdowns come from initial failure, chance failure and wear out failures are well known. MTTR's are known and stable. Needs of training on maintenance have been identified. Definition of EOQ and ROP based on consumption and spares are stored in defined areas. 

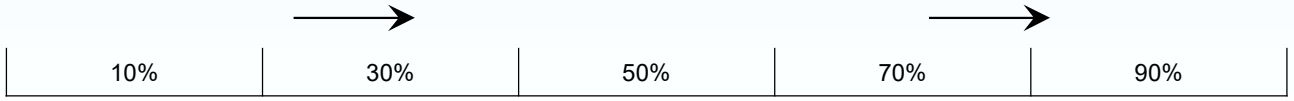
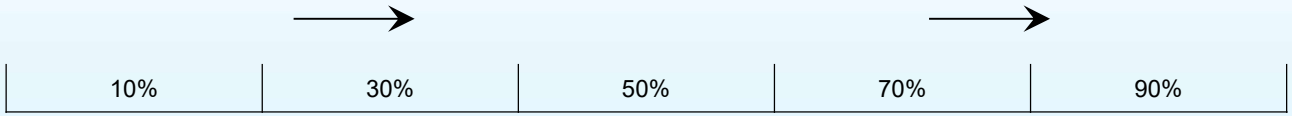
Step 2 : Conduct breakdown analysis and reverse deterioration

Level 1	No breakdown analysis. No lubrication plan.
Level 2	Breakdown analyses have been carried out, but still lack in illustrating breakdown phenomena with proper sketches. Lubrication is carried out on points already known. Training on maintenance is carried out, but still lack of analysis of the results. 
Level3	A lot of breakdown analysis with 5W1H plus sketches of breakdown phenomena have been made for major breakdowns and effective countermeasures have been found and implemented with good results. 

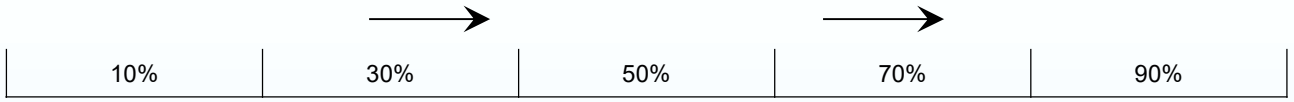
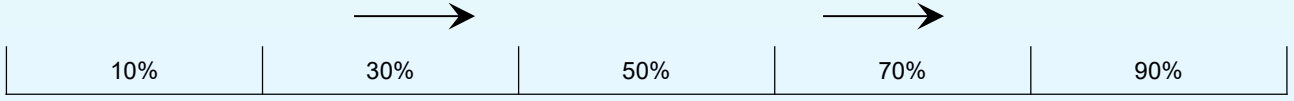
Level 4	Lubrication is carried out following the lubrication standards. More than 90% of major breakdowns were analyzed and countermeasures for more than 80% of the analyses were identified. More than 80% of the countermeasures were implemented and more than 50% have been effective. 
Level 5	Effective breakdown analyses for all major machines have been carried out and substantial reduction of machine breakdowns has been achieved. Almost no repetitive breakdowns take place. Training on maintenance is well established and the analysis of the effect is made. The contents of shutdown maintenance is well planned and it works in substantially reducing unexpected breakdowns. 

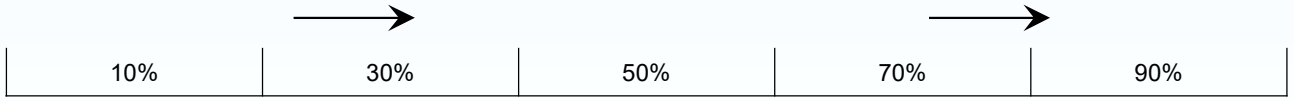
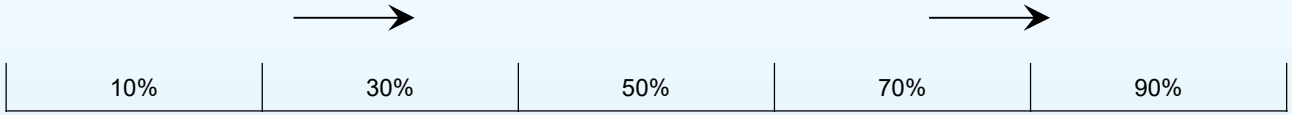
Step 3 :Establish maintenance standards and introduce periodic maintenance

Level 1	No periodic maintenance schedule is defined.
Level 2	The time spent on BM is still bigger than the one spent on Preventive Maintenance. 
Level 3	Tasks are clearly defined for PM and AM. Advanced lubrication system is used. Breakdowns caused by poor maintenance is almost nil. BM = PM 

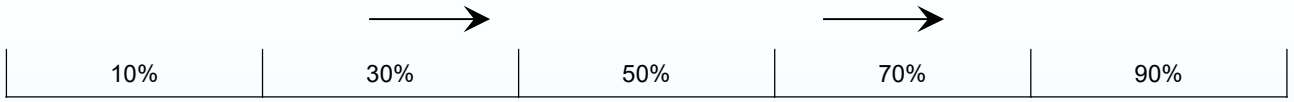
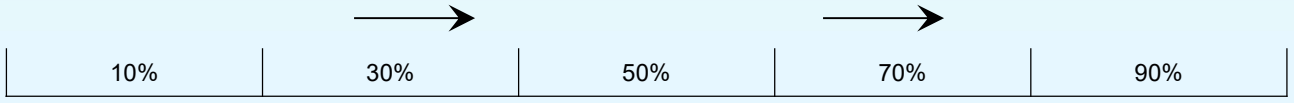
Level 4	BM PM The planned maintenance covers more than 70% of the possible breakdowns. 
Level 5	Maintenance calendars for major machines have been established and more than 90% of the planned maintenance work is carried out as planned with a good result. The maintenance plans are frequently revised based on results giving continual improvement with maximum involvement of production. Shutdown maintenance is efficient and effective. Spare parts management is well made. 

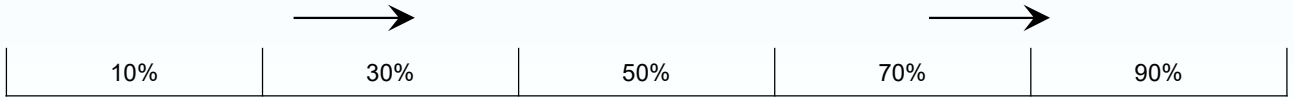
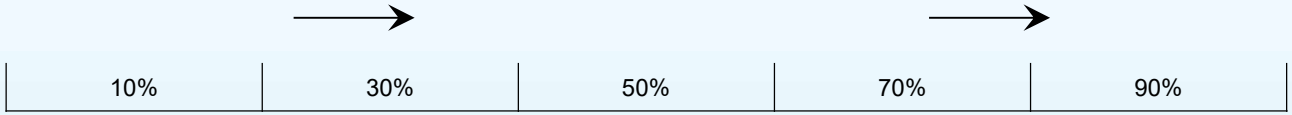
Step 4 : Countermeasures against design weaknesses

Level 1	No activity of corrective maintenance is carried out.
Level 2	Design weaknesses of equipment and components weaknesses have been recognized. 
Level 3	More than 30% weaknesses of equipment and components weaknesses have been corrected effectively. 

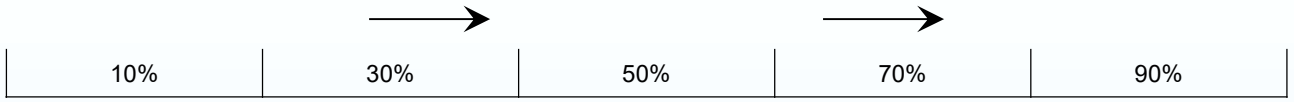
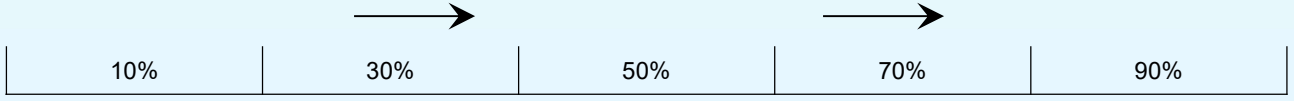
Level 4	More than 50% weaknesses of equipment and components weaknesses have been corrected effectively. 
Level 5	For major machines and major components, their MTBF's are known and their weaknesses are constantly corrected for longer life times, easiness of measuring deterioration and shorter MTTR by the cooperation with their suppliers. Cleaning, inspection and lubrication times have been minimized. 

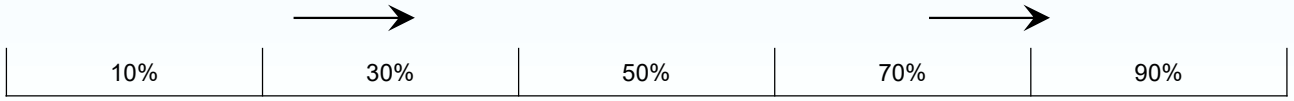
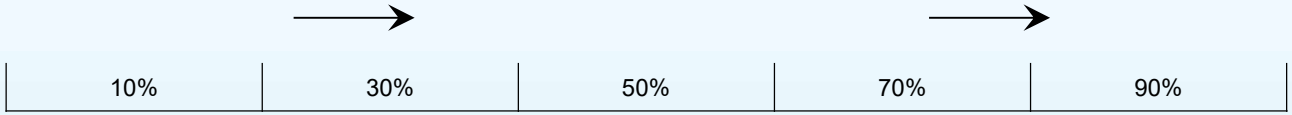
Step 5 : Build a periodic maintenance system

Level 1	No adjustment of periodic maintenance and shutdown maintenance are made yet.
Level 2	Revised periodic maintenance and shutdown maintenance based on corrective maintenance. 
Level 3	Frequently revised periodic maintenance and shutdown maintenance with tasks clearly defined for PM and AM. Operators can cover more maintenance activities. 

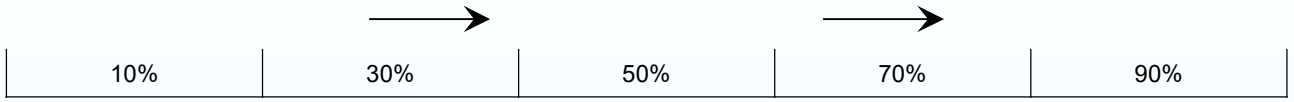
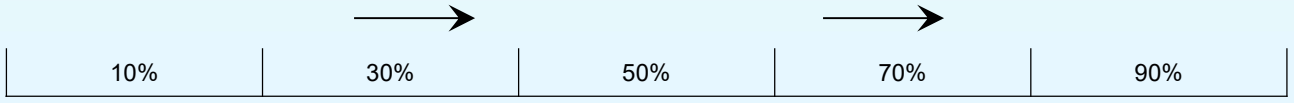
Level 4	Periodic maintenance and shutdown maintenance based totally on countermeasures for FMECA/RCM. Periodically updated. 
Level 5	Well established periodic maintenance and shutdown maintenance (ca. : twice a year). Spare parts management is well established but not yet involved EEM to standardize spare parts. 

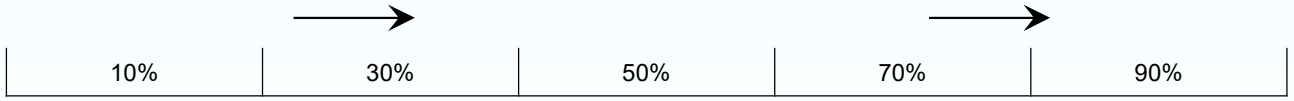
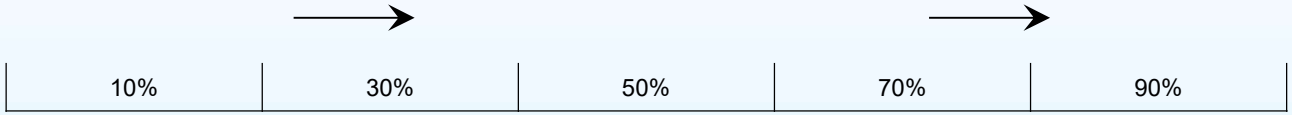
Step 6 : Build predictive maintenance system (trend management)

Level 1	No Predictive Maintenance is carried out.
Level 2	Training of CBM is available and studied. Major tools applied with limited results. 
Level 3	Parameters to measure component conditions are well known and all applicable tools are identified and mastered. 

Level 4	Plan followed and cost effective but results not utilized effectively. 
Level 5	Effective analysis of results with continuous improvement of plan. Used to control spare parts. 

Step 7 : Establishment of planned maintenance and maintenance cost management systems

Level 1	CMMS is not available.
Level 2	CMMS exists, but lack of information in detail. Only basic information. 
Level 3	Good detail for all maintenance parameters with archives. Supports breakdown analysis. Detail and information sufficient but only split into labor, materials and contractors but not used effectively. 

Level 4	Information used effectively with a complete cost analysis by component, resulting in reducing maintenance intervention time. Information split by maintenance type with material consumption, labor, cost of contractors. Periodically updated. 
Level 5	Machine breakdowns are almost nil. Purchase of spare parts is made based on the planned maintenance and shutdown maintenance. MP information is available to be fed back to EEM. 

4. Shutdown Maintenance

4.1 The Feature of Shutdown Maintenance

4.2 Work Breakdown Structure for Shutdown Maintenance

4.3 WBS

4.4 Shutdown Maintenance Management (Example)

4.5 Equipment Diagnosis During Plant Operation and Shutdown

4.6 Concluding Shutdown Maintenance

4.7 Items Recorded on Shutdown Maintenance Report

4.8 Weekly Shutdown Maintenance Report (Sample)

4.9 Maintenance Standards

Shutdown Maintenance

Building a planned maintenance system should be done systematically, one step at a time.

- Planned maintenance activities emphasize monitoring mean times between failures (MTBF).
- The analysis should be used to specify the intervals for tasks in annual, monthly and weekly maintenance calendars.
- A typical example of planned maintenance activity is **shutdown maintenance.**
- The goal is to lay out reliable plans before the job begins.

Shutdown Maintenance

- Because the tasks performed during shutdown maintenance follow a set pattern, it is helpful to base the work plan on a work breakdown structure (WBS) diagram.
- This diagram facilitates accurate estimation of the tasks to be performed during shutdown maintenance, along with their sizes.
- It can be used to gauge the staff and materials needed for the job and to monitor the budget and the achievement of the objectives.

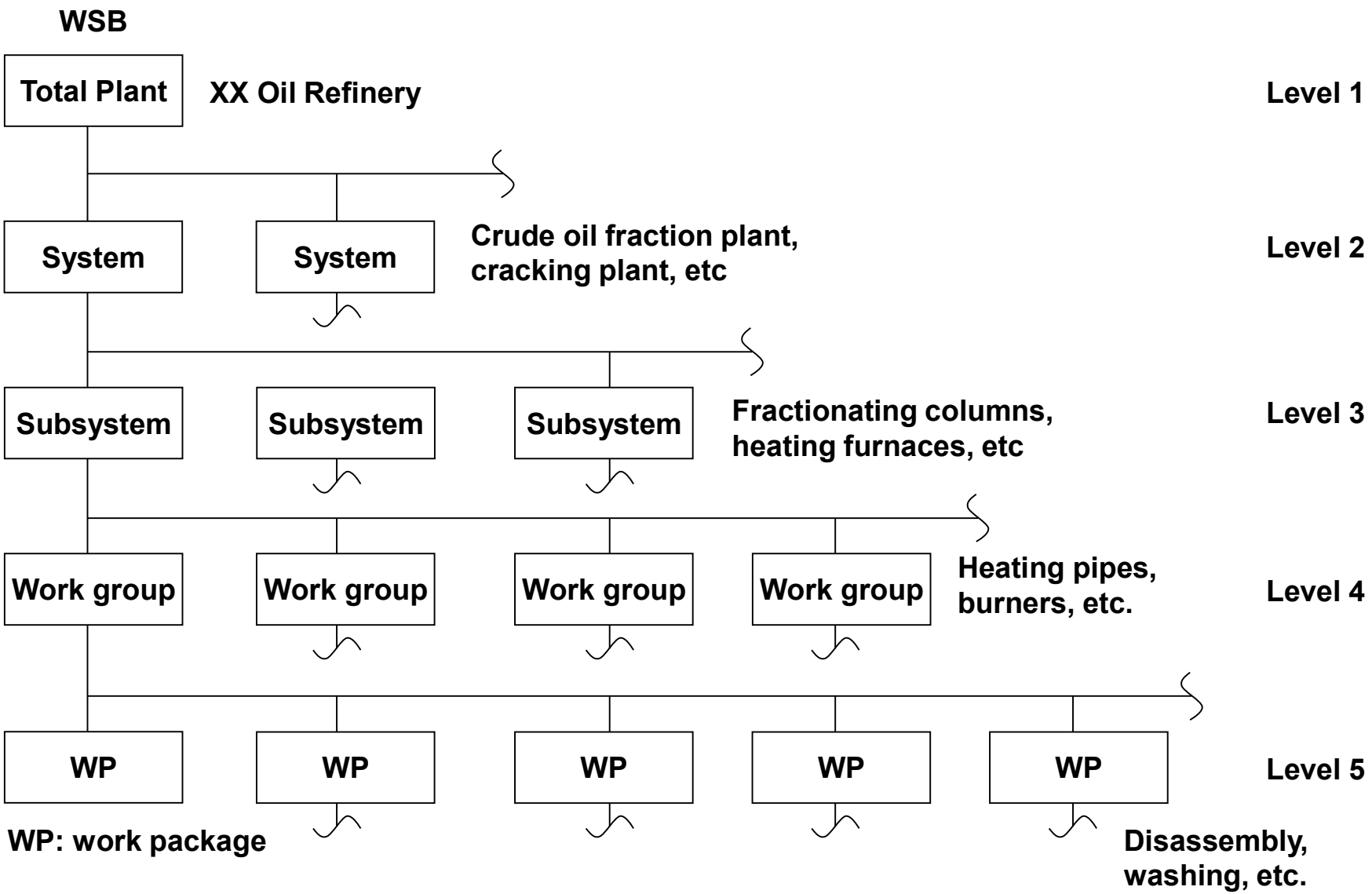
Work Breakdown Structure for Shutdown Maintenance

1. **Omission-free, error-free shut down maintenance is impossible unless the entire process is carefully planned**
2. **List every single maintenance task, regardless of size, and relate each to the each others by means of a work breakdown structure (WBS) Diagram**

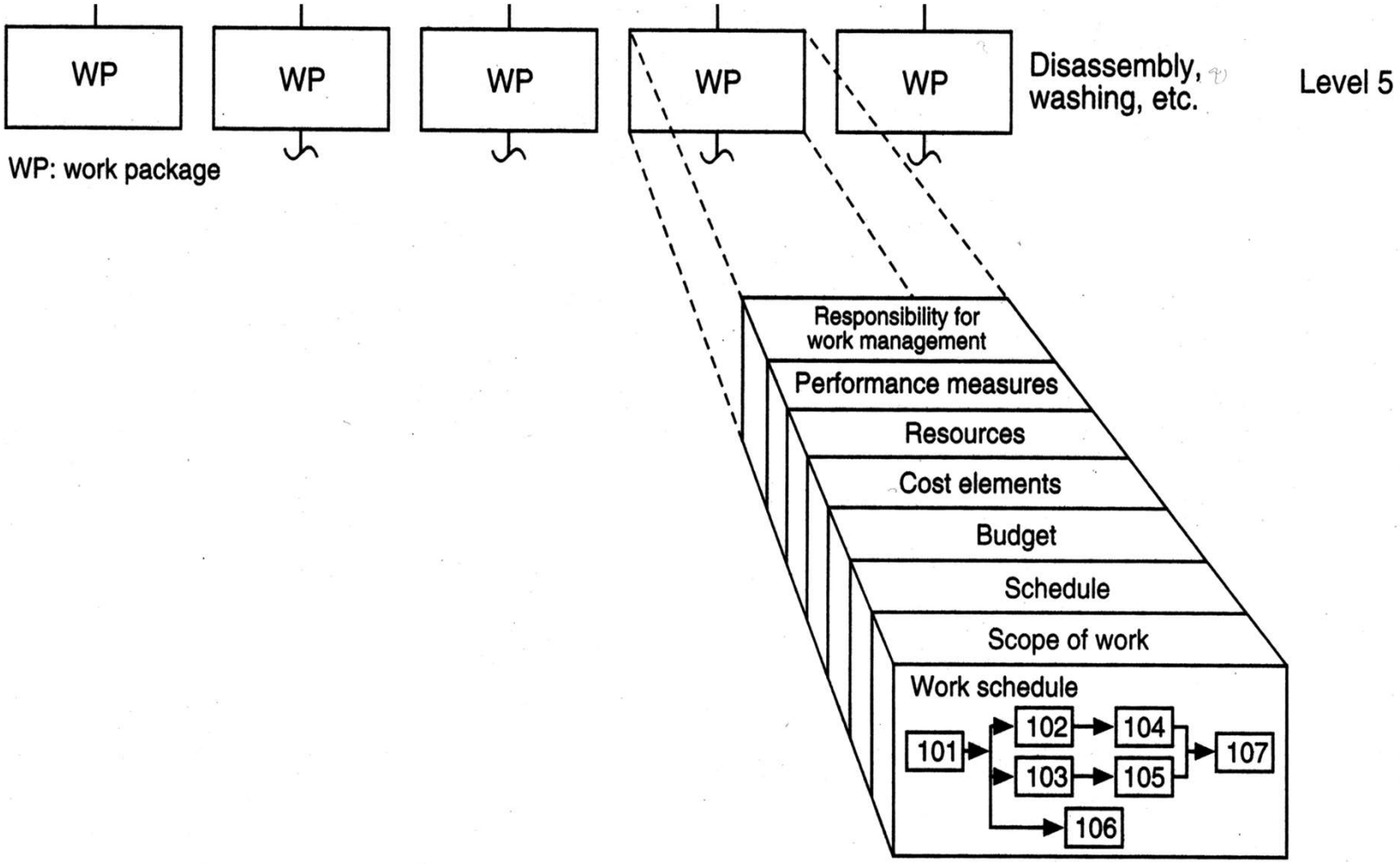
The WBS method includes the following activities:

- Prepare an on-site work operation sheet in network from that clearly shows the relationship among different tasks.
- Prepare a network diagram. Shorten the process and Highlight the bottleneck process.
- Reduce shutdown maintenance costs.
- Make effective use of subcontract work normally employed on daily maintenance.
- Select subcontractors by competitive tendering based on shutdown maintenance work standards.

Work Breakdown Structure (WBS)



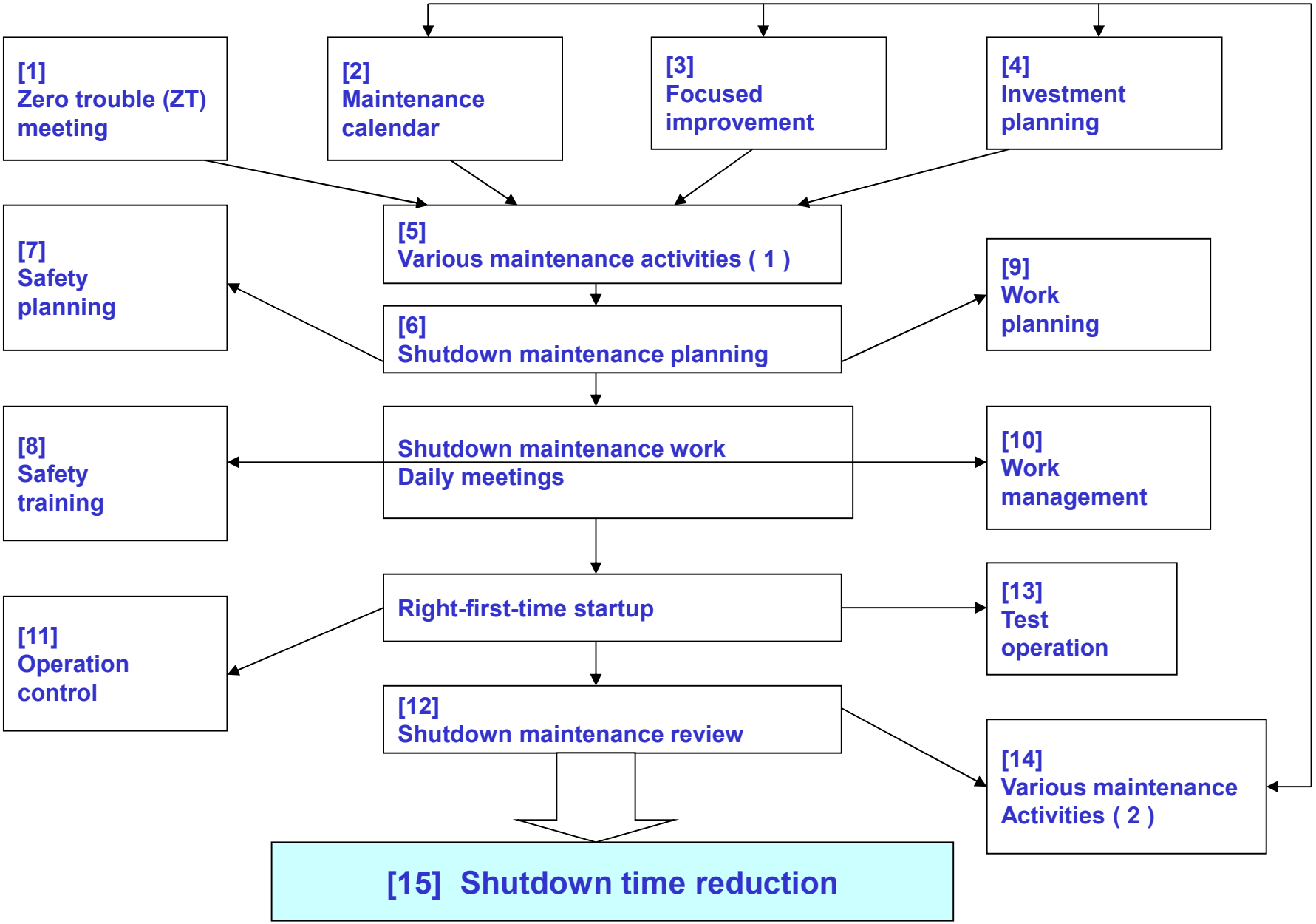
Work Breakdown Structure (WBS)



Shutdown Maintenance Management (Example)

No matter how skill-fully personnel carry out the work, the result cannot be fully effective from the maintenance viewpoint, unless information gathered during operation and relevant to the work is taken into consideration in the plans

Enhanced Planning of Shutdown Maintenance



Enhanced Planning of Shutdown Maintenance

[1] Zero trouble (ZT) meeting

- Outstanding trouble cards

[2] Maintenance calendar

- Overhaul inspection
- Inspection and service
- Functional check

[3] Focused improvement

- Equipment improvement

Enhanced Planning of Shutdown Maintenance

[4] Investment planning

- Replacement of obsolete equipment
- Production increases, labor-saving, energy-saving

[5] Various maintenance activities (1)

- Utilization of MP information
- Improvement of equipment diagnostics
- More promotion of reliability and maintainability improvement
- Enhanced early management

[6] Shutdown maintenance planning

- Identification of items, discussion of contents, overall schedule coordination, budget control

Shutdown Maintenance Liaison Committee (meets monthly)

Enhanced Planning of Shutdown Maintenance

[7] Safety planning

- Equipment modification permit application
- Repair work permit application
- Safety certificate
- Flammable materials use permit application
- Immersion work permit application
- Safety discussions
- General accident prevention conference

Enhanced Planning of Shutdown Maintenance

[8] Safety training

- Preparation for shutdown
- Work safety measures
- Witnessed inspection of work
- Daily meetings
- Safety patrols
- One-point safety bulletins

Enhanced Planning of Shutdown Maintenance

[9] Work planning

- MP meeting
  - Work specifications
  - Schedule coordination
  - Raw materials purchase
- Daily handling of problems
- Shutdown maintenance work summary
- Revising inspection intervals and methods
- Improving work execution methods
- Strengthening negotiations with government agencies
- Establishing schedule control

Enhanced Planning of Shutdown Maintenance

[10] Work Management

Work quality

Schedule control

Acceptance

} **Startup management**

- Defect follow-up system (problems remaining after inspection)
- Campaign to eliminate waste, variability and strain

[11] Operation control

- Test operation planning
- Preparation for startup
- Operator training

Enhanced Planning of Shutdown Maintenance

[12] Shutdown maintenance review

- Inspection and servicing records
- Preparation for next year's shutdown maintenance

[13] Test operation

- Rotation direction check
- Vibration check
- Startup management

[14] Various maintenance activities (2)

- Modification of maintenance calendar
- Obsolete equipment replacement plans
- Equipment improvement plans
- Specialized maintenance education

Enhanced Planning of Shutdown Maintenance

[15] Shutdown time reduction

Plant A : 44 days -- 35 days ($160,000/day)

Plant B : 27 days -- 20 days ($160,000/day)

Shutdown maintenance cost reduction

Plant A : $3.44 mill./year -- $2.96 mill./year

Equipment Diagnosis During Plant Operation and Shutdown

Diagnosis during Operation	Diagnosis during Shutdown
Principally rotating machinery and static equipment abnormalities diagnosed from process abnormalities.Usually done by operators monitoring the process or performing roving checks. Factors analyzed include: • Equipment abnormality (from instrument panel readings) • vibration in rotating machinery and other equipment • Leaks • Abnormal sound • Abnormal temperature • Lubricant • Odor • Blocks	Principally of static equipment. Includes long-term diagnosis of material deterioration (hydrogen attack, creep, carburization, stress corrosion cracking, fatigue). Types of inspection include: • Overhaul of static equipment • Overhaul of large rotating machines not provided with backup • Materials of large in static equipment (hydrogen attack, creep, carburization, stress corrosion cracking, fatigue, etc.) • Welds • Wall thickness in high-temperature piping

Concluding Shutdown Maintenance

1. At the conclusion of shut down maintenance, prepare a report that details the work accomplished, the progress made, the organization used, the budget, and so on.

2. Be careful to report all problems that concern safety, progress, and budget, and use this information in planning the next shutdown maintenance project

Items Recorded on Shutdown Maintenance Report

1. Shutdown maintenance schedule	• Planned (network diagram) — indicate critical path • Actual (network diagram) — indicate actual critical path, with reasons • Planned (calendar) — daily worker numbers, cranes, heavy machinery, government inspections • Actual (calendar) — actual daily worker numbers, cranes, heavy machinery, government inspections, weather
2. Shutdown and startup schedule	• stop operation • commence work • planned and actual • problems **Work completion** • normal operation • scheduled and actual • problems
3. Organization for shutdown maintenance	• Actual organization employed • Points to incorporate in next shutdown maintenance plan

Items Recorded on Shutdown Maintenance Report

4. Description of principal work performed **5. Safety and environmental problems** **6. Work problem, improvement measures adopted**	
7. Budgeted and actual expenditure	• materials cost • subcontracting cost
8. Subcontracted work	• work undertaken by each subcontractor • planned and actual numbers of works entering site
9. Government inspections	
10. Shutdown maintenance inspection	• problems (attach separate inspection report)
11. Shutdown maintenance debriefing (SDM) in principle: **SDM debriefing for next SDM** **Scheduling meeting for next SDM** **Planning meeting for next SDM** **Work meeting for next SDM**	• schedule for next SDM • within two months after completion • three months before date • within four month after completion • two months before date
12. Other items to note in planning and implementing next SDM	

Weekly Shutdown Maintenance Report (Sample)

GENERAL

- No injures to company or subcontractors' employees
- Progress of shutdown maintenance work: 97-98%

SHUTDOWN MAINTENANCE

Plant C: A tube leak test revealed leaks in the ends of three reactor discharge oil/free heat exchangers. One was due to a leak in the sealing weld of a tube plug. The other two were due to cracked tube ends.

All have been repaired. Reactor catalyst charging has been completed.

Plant B: Based on the results of γ-radiation inspection of heating furnace tubes after decoking, the decoking operation was repeated.

Plant A: Tray leak test satisfactory; inspection cover replacement commenced.

None of the above problems has affected overall progress.

NET WORK

Plant B: Testing revealed that several of the 32 tray-washing spray nozzles were blocked.

A 10-mesh strainer will be attached to the pump outlet, and the line scoured by air jet.

The work is on schedule.

GOVERNMENT INSPECTIONS

Plant C: 8/22 fire safety

Plant D and E: 8/25 fire safety, high-pressure gas

Plant B: 8/26 fire safety

Plant A: 8/29 fire safety

SPECIAL ITEMS

None

Maintenance Standards

Major Category	
1. Maintenance management standards	
Medium Category	Content
1. Management standards	An organization to implement equipment maintenance management smoothly; an activity structure; the basic items of management such as evaluation of equipment effectiveness, etc; spare parts management, lubricant management, equipment clarification criteria, maintenance budget management, maintenance information management, maintenance administration, maintenance procedures, etc. which are necessary for the execution of effective maintenance and technical information. The responsibilities of each staff of the maintenance division, etc.The procedure of establishing and revising the maintenance standards.
2. Maintenance technique standards	Common maintenance techniques should be made available.

Major Category	
2. Equipment maintenance standards	
Medium Category	Content
1. Equipment inspection standards (For measuring the deterioration of equipment)	These are the standards for inspection of equipment, in other words, inspection and measurement methods to check the degree of equipment deterioration. The contents are parts to be inspected, inspection points, items, cycles, inspection methods, measuring apparatus, judgment criteria, etc. Depending on the necessity, charts and pictures should be attached. Depending on the types of inspection, there are daily inspection standards (The cycle is within 1 month) and periodic inspection standards (The cycle is more than 1 month) by cycle; there are performance inspection standards and accuracy inspection standards by item; machine equipment inspection standards, electric equipment inspection standards, piping inspection standards, instrumental equipment inspection standards by object.

2. Servicing standards (For preventing the deterioration of equipment)	These are the standards for the conditions and methods of daily maintenance such as cleaning, oil change, inspection, adjustments and parts replacement. Depending on the types of servicing standards, cleaning standards, oil changing standards, the adjustment standards of the cleaning, oil charging, inspection standards should be set. As for the oil charging standards, oil charging method, oil types, the charging amount of oil and cycles should be specified.
3. Repair standards (For restoring the deterioration of equipment)	These are the standards for conditions and methods of repair concerning specific equipment or equipment parts. The repair standards are often specified as maintenance operation standards, including operation method and operation time.

Major Category	
3. Maintenance operation standards	
Medium Category	Contents
(for indicating the maintenance operation, procedures and timing)	This is created for operation which has a high frequency of occurrence. This is useful for the measurement of work group efficiency or estimation of maintenance work time and man power management, and schedule planning as well as education and training of new employees.

5. Establishment of CBM

5.1 Points of Choosing CBM
5.2 Procedure of Developing an Equipment Diagnosis Technique
5.3 How to Advance Predictive Maintenance
5.4 Transfer to Equipment Diagnosis Techniques
5.5 Methods and Their Contents of Predictive Diagnosis
5.6 Measurement Units and Measuring Devices
5.7 Diagnosis Techniques for Static Equipment
5.8 Diagnostic Equipment for Rotating Equipment
5.9 Major Equipment Diagnosis Technologies and Their Overview Functions
5.10 Predictive Maintenance Flow Diagram
5.11 Introducing Vibration Diagnosis for Rotating Machinery
5.12 Develop Predictive Maintenance

Points of Choosing CBM

1. When a breakdown takes place, it will influence production output substantially.
2. Sporadic breakdowns often take place.
3. Breakdowns cannot be prevented by a normal inspection and servicing.
4. The period between two consecutive breakdowns are relatively long.
5. Because of deterioration, breakdowns often take place.
6. The progress of deterioration is relatively slow.

Procedure of Developing an Equipment Diagnosis Technique

- **Specify a part requiring diagnosis based on the past experiences of serious failures.**
- **Investigate what kind of deterioration pattern the part has.**

  Does deterioration gradually takes place as time passes?

- **Try to grasp the deterioration characteristics by an alternative physical quantity.**

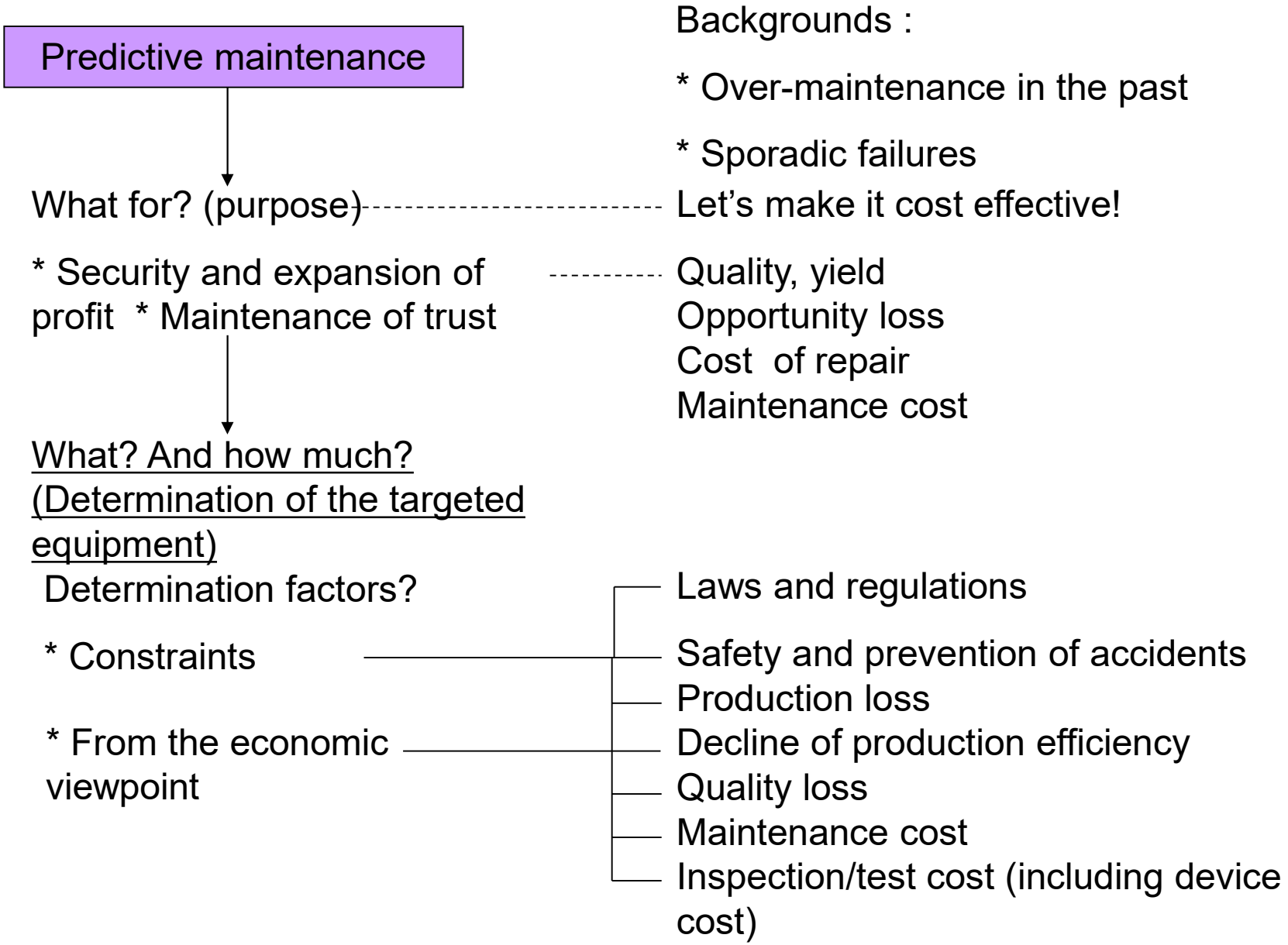
  What parameters (physical units)?

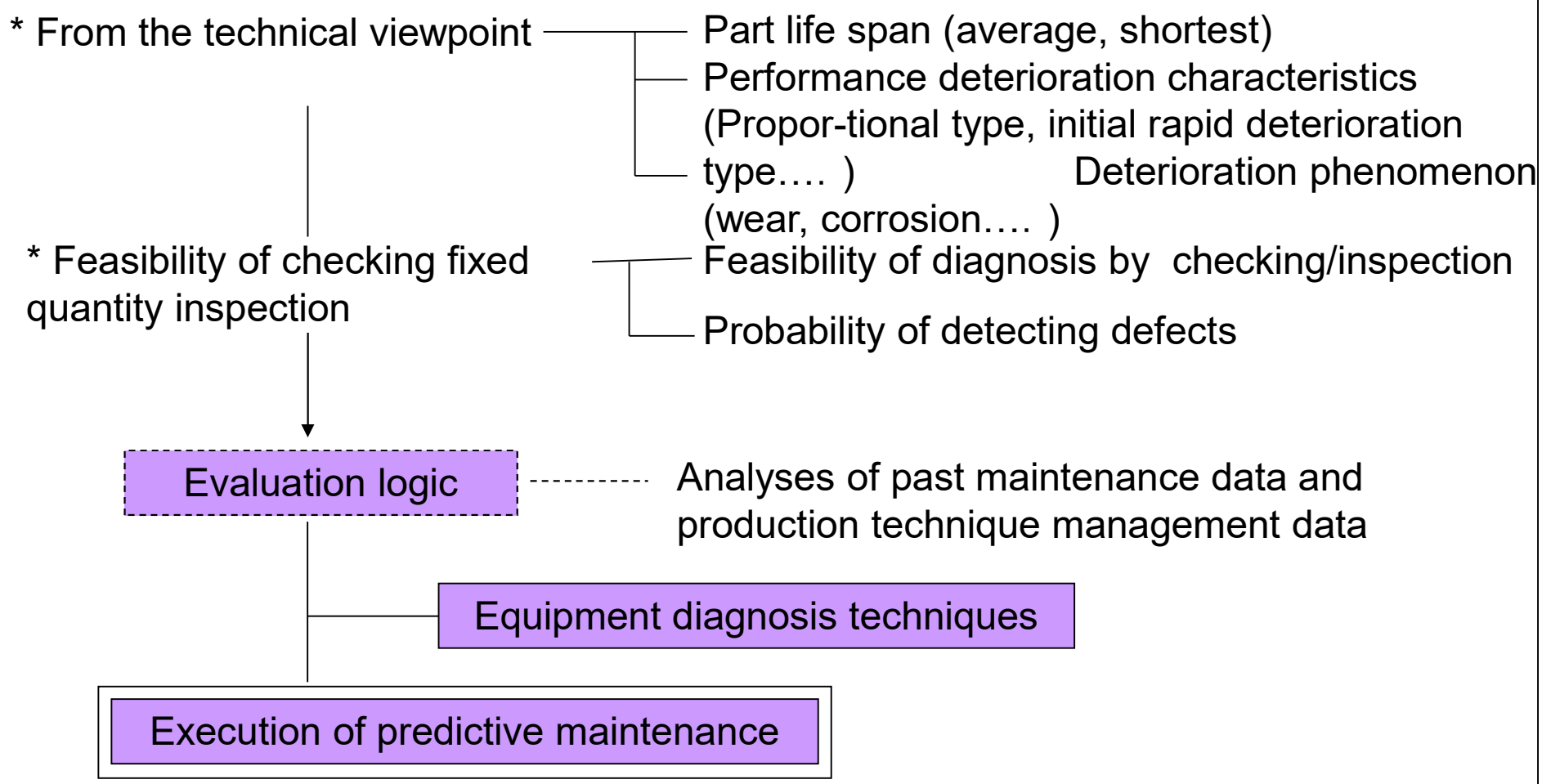
  Vibration? Displacement, speed or acceleration speed?

- **Establish a technique to measure deterioration.**

  Try to use available techniques such as vibration measurement, etc. from the shelf.

How to Advance Predictive Maintenance




* From the technical viewpoint
Part life span (average, shortest)
Performance deterioration characteristics
(Propor-tional type, initial rapid deterioration type….)
Deterioration phenomenon
(wear, corrosion….)
* Feasibility of checking fixed quantity inspection
Feasibility of diagnosis by checking/inspection
Probability of detecting defects
Evaluation logic
Analyses of past maintenance data and production technique management data
Equipment diagnosis techniques
Execution of predictive maintenance

Transfer to Equipment Diagnosis Techniques

What is diagnosis?

Grasp conditions quantitatively

Possible to grasp at a unit level

Element to be diagnosed
• Degree of deterioration

Possible to grasp at equipment level

Equipment diagnosis
• Degree of performance
(Pursuit of the causes of abnormal phenomena)

Statistical method

Life anticipation

Implementation of countermeasures

• Determination of the most appropriate timing and cycle of maintenance
• Reduction of sporadic failures
• Improvement of efficiency, quality and yield

Methods and Their Contents of Predictive Diagnosis

Diagnosis method	Diagnosis contents
Temperature method	This is the method to conduct equipment diagnosis by measuring the temperature and to know the irregularities of the equipment from clues of temperature.
Pressure method	This is the method to conduct equipment diagnosis by measuring the pressure and to know the irregularities of the equipment from clues of pressure loss and lost pressure.
Vibration method	This is the method to conduct equipment diagnosis by measuring the vibration and to do equipment diagnosis by the detection of the amount of displacement and/or the change of acceleration speed.
Oil analysis method	This is the method to conduct diagnosis by analyzing the operation oil, lubricant, insulation oil, etc. which are used for the equipment.
Liquid penetrant method	This is the method to test for material surface opening defects by dying penetrant or fluorescence penetrant, etc.
Dimension measuring method	This is the method to conduct equipment diagnosis by measuring the dimensions of machinery and to know any irregularity of the equipment by a change of the dimensions.
Insulation measuring method	This is the method to know the irregularities of the machinery by measuring the insulation resistance value for electric equipment or electric wiring.
Electric resistance method	This is the method to know the irregularities of the machinery by measuring the electric resistance value for electric equipment.

Measurement Units and Measuring Devices

No.	Item measured	Measurement tool
1	Axle looseness	Dial gauge, small test
2	Edge wobble	Dial gauge, small test
3	Linearity	Autocollimator
4	Flatness	Autocollimator, laser-mediated flatness gauge
5	Orthogonality	Laser coordinate measuring machine
6	Cycle line drawing	Visigraph
7	Belt tension	Tension meter
8	Looseness	Dial gauge, spring balance
9	Vibration	Vibration analyzer, FFT
10	RPM	Tachometer, vibrotester
11	Rotational abnormalities	Vibrotester
12	Grindstone balance	Vibrotester

Measurement Units and Measuring Devices

No.	Item measured	Measurement tool
13	Frequency	Oscilloscope
14	Load current	Ammeter, pen recorder
15	Power	Wattmeter
16	Resistance	Insulation tester
17	Temperature	Thermometer
18	Temperature distribution	Radiation thermometer (thermotracer)
19	Warping	Warp meter
20	Bolt fastening strength	Torque wrench
21	Torque	Torque meter
22	Force	Load scale, spring force meter
23	Pressure	Pressure gauge, micro pressure gauge
24	Outside(major) diameter	Micrometer, dial gauge

Measurement Units and Measuring Devices

No.	Item Measured	Measurement tool
25	Inner diameter measurement	Cylinder gauge, air micrometer
26	Roundness	Roundness meter
27	Cylindricality	Length measuring machine
28	Surface roughness	Surface roughness gauge
29	Cut surface chatter	High-resolution roughness gauge
30	Abrasion	Dimension gauge
31	Hardness	Hardness gauge
32	Surface hardness (for thin items)	Superficial hardness gauge
33	Fit	Blue
34	Residual stress	X-ray residual stress meter
35	Residual magnetism	Gaussometer

Measurement Units and Measuring Devices

No.	Item Measured	Measurement tool
36	Grinding crack	Acid bath test, hydrochloric acid macro test
37	Backlash	Thickness gauge
38	Gear mesh	Gear mesh tester
39	Angle	Angle gauge, autocollimator, rotary encoder
40	Hydraulic fluid contamination	Automatic microscopic particle counter
41	Coolant contamination	Millipore
42	pH	pH meter, chemical analysis

Measurement Units and Measuring Devices

No.	Item Measured	Measurement tool
43	Air cleanliness	Particle counter
44	Sound	Noise meter, FFT
45	Brightness	Illumination meter
46	Flow rate	Flow meter
47	Horizontal level	Level gauge
48	Line centering	Piano wire
49	Ingredients, composition	X-ray micro analyzer, electron microscope

Diagnostic techniques for Static Equipment

Abnormality	Cause	Diagnostic technique	Equipment
COLUMNS/TANKS Leak	Corrosion, cracking, leaky packing	Visual inspection, soapy-water test, gas detection, wall-thickness measurement	Color-forming or foaming liquids, magnetic-powder flaw detectors, ultrasonic thickness gauges, gas detectors
Vibration	Transmission from outside	Vibration measurement	Vibration meter
	Abnormal gas/liquid flow	Analysis of operation conditions	Frequency analyzer, operating records
Internal contamination	Corrosion, abnormal internal fluids	Check operating conditions, analyze discharge	Radioscope, operating records
PIPING Leaks	Corrosion erosion, perforation	Visual inspection gas detection, foaming liquid test	Gas detector, magnetic-powder flow detector, ultrasonic thickness gauge
	Leaky packing and gaskets	Thickness measurement	

Diagnostic techniques for Static Equipment

Abnormality	Cause	Diagnostic technique	Equipment
Blocks	Stuck valves, foreign matter, accumulated sludge	Pressure-drop measurement, radioscopy	Pressure gauge, radioscope
Vibration	Resonance with rotating machinery vibration	Vibration measurement	Vibration meter
	Abnormal fluids flow	Investigate operating conditions	Operating records
	Abnormal supports	Visual inspection, vibration measurement	Vibration meter
Deformation, bending	Abnormal hangers and supports	Displacement measurement	Scale, level gauge, transit theodolite
	Abnormal external force, thermal stress	Check external forces and temperatures	Operating records

Diagnosis Technique for Rotating Equipment

Equipment	Parts	Diagnosis item	Diagnosis method
Fan blower pump motor	Impeller	Unbalance	Vibration method
	Coupling	Core slippage	Vibration method
	Bearing	Abrasion	Vibration method
		Flaking	Temperature method
	Foundation	Backlash/looseness	Vibration method
Reduction gears	Bearing	Abrasion	Vibration method
		Flaking	Vibration method
	Gear	Pitching	Oil analysis method
			Temperature method
	Coupling	Core slippage	Vibration method
	Foundation	Backlash/looseness	Vibration method
Hydraulic equipment	Bearing	Abrasion	Vibration method
		Flaking	Oil analysis method
	Vane	Abrasion	Vibration method
	Plunger	Chipping	Oil analysis method
	Packing	Abrasion	Pressure method

Extruder	Bearing	Abrasion	Temperature method
		Flaking	Oil analysis method
	Gear	Pitching	Oil analysis method
Mechanical equipment	Tank	Corrosion	Dimension measuring method
		Abrasion	Dimension measuring method
	Foundation	Cracking	Liquid penetrant method
	Wire	Abrasion	Dimension measuring method
	Chain	Abrasion	Dimension measuring method
Electric equipment	Transmission	Insulation deterioration	Oil analysis method
	Cable	Insulation deterioration	Insulation measuring method
	Heater	Life span	Electric resistance method

Major Equipment Diagnosis Technologies and Their Overview Functions

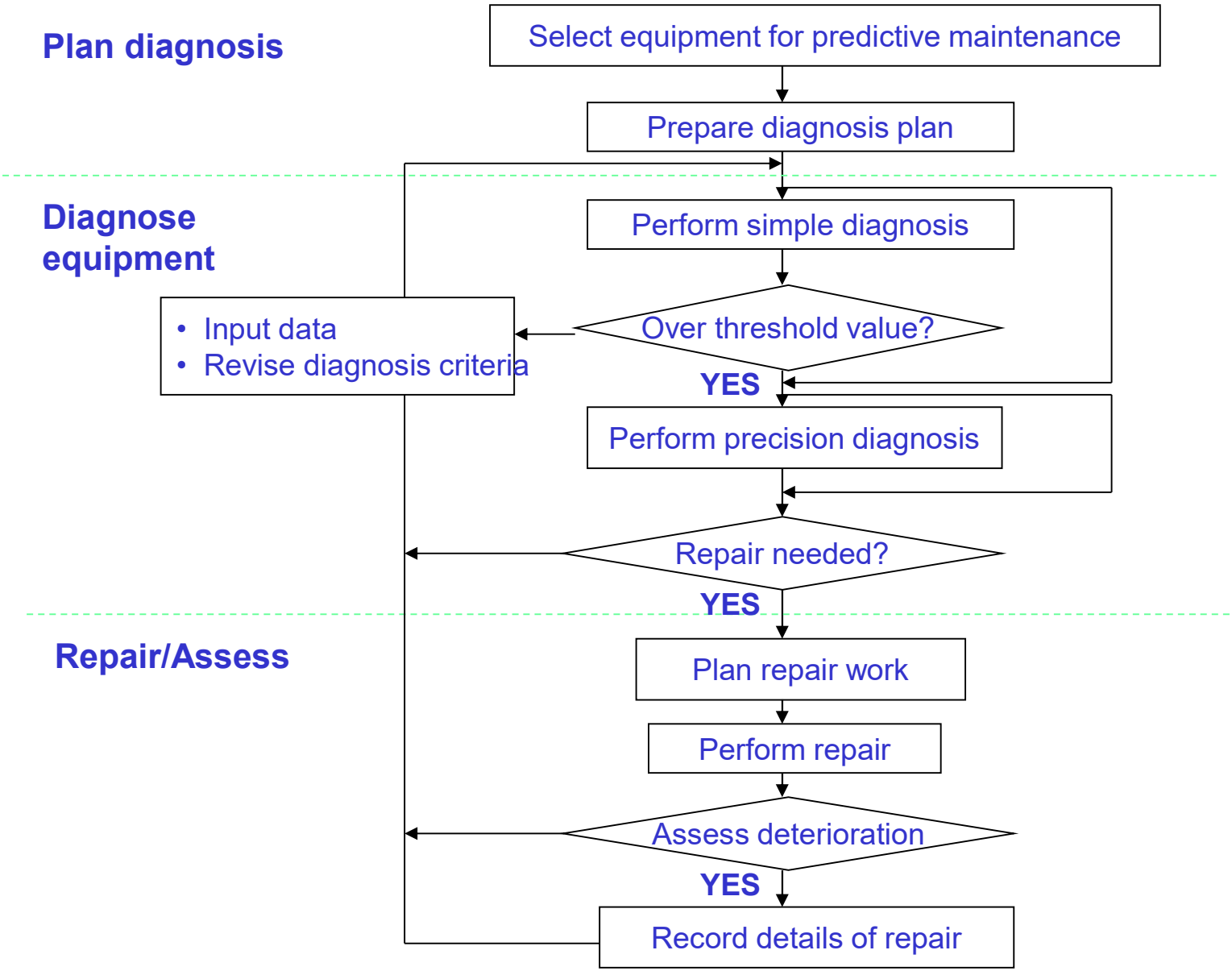
Major Category				
Mechanical equipment of diagnosis				
Categories	Diagnosis	Simple / Precision	Diagnosis equipment	Outline
Rotating machine diagnosis technique	Diagnosis of bearings, gears and rotary mechanisms	Simple diagnosis	Machine checker	From the amount of vibration generated by the machine, the imbalance of gears, bearings and rotors are diagnosed as good or bad.
	Bearing diagnosis technique Gear diagnosis technique Rotary mechanism diagnosis technique Field balance technique	Precision diagnosis	Rotary machine diagnosis device	By the analysis of vibration waveform or vibration modes, the degree, position and causes of deterioration of the gears, bearings and rotary mechanisms should be judged.
			Machine signal measurement device	Signals of vibration, pressure, etc. are processed and disposed for easy analysis.
			Universal signal analysis device	Since frequency resolution power is very strong, the vibration waveform can be analyzed for the ultra precision diagnosis. The conditions of bearings and gears can be diagnosed.

Crack diagnosis technique	Acoustic emission method	Precision diagnosis	Crack monitor	By detecting the sound generated at the time of crack development, the degree and the level of danger of crack development can be diagnosed.
Lubrication diagnosis techniques	Ferrography abrasive chips in oil analysis method	Precision diagnosis	Ferrography analysis device	By the shapes or sizes of abrasive chips in lubricant, the condition of the sliding surface can be judged.
Major Category				
Electric equipment diagnosis				
Categories	Diagnosis	Simple / Precision	Diagnosis equipment	Outline
Rotating electric machine diagnosis	Insulation diagnosis technique	Simple diagnosis	Super mega (DC high voltage method)	By the changes of insulation resistance over the time, the humidity and damage of the insulation can be judged.
		Precision diagnosis	Automatic insulation diagnosis device (AC high voltage method)	By the size, phase, degree of changes of the leakage current (current in the ground wire) when AC high voltage is imposed, the degree of deterioration of insulation can be judged.

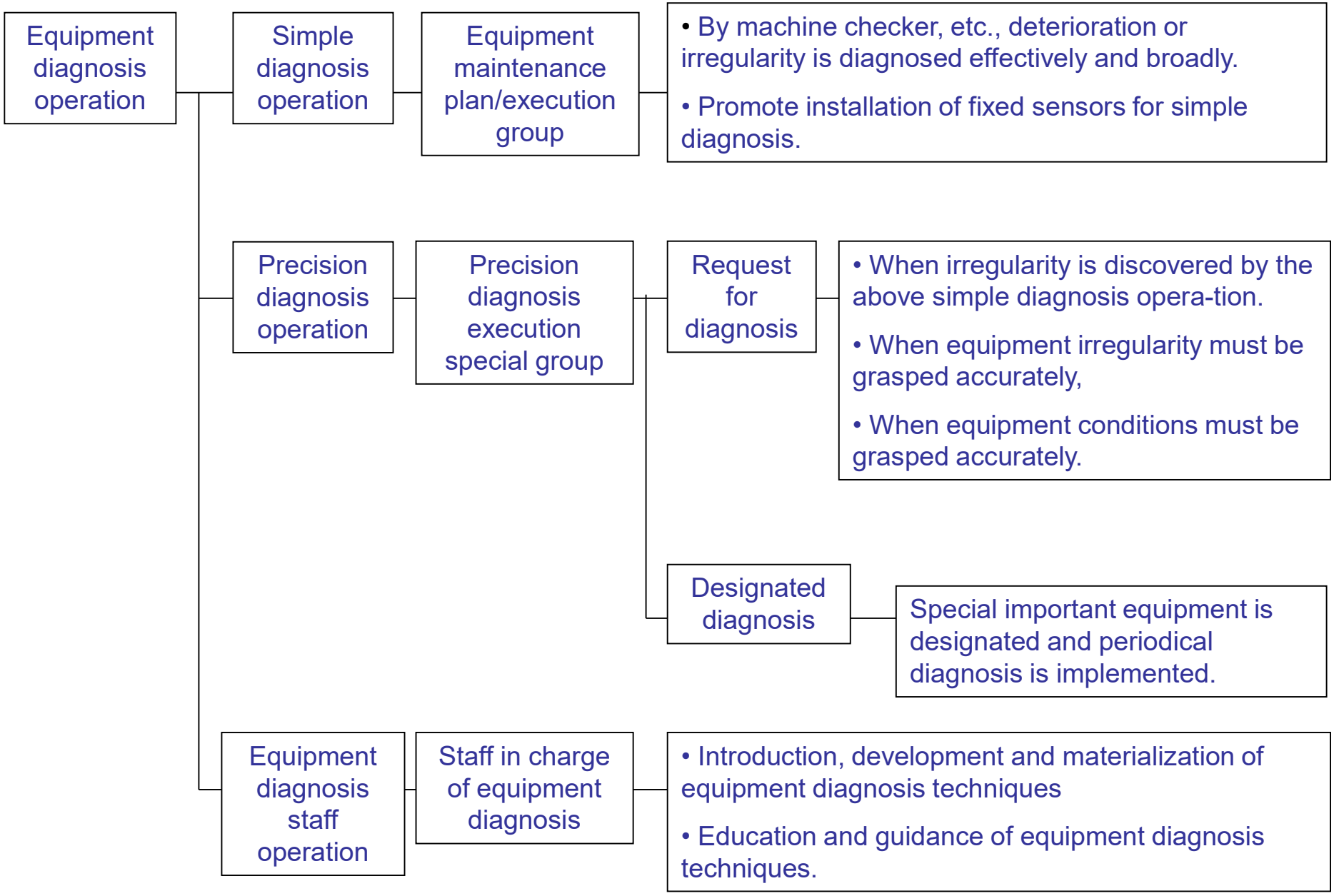
	Coil diagnosis technique	Precision diagnosis	Electric coil diagnosis device	By the size, duration, changes of vibration frequency when big current surge is imposed on the coil and vibrated, the loosening of the coil due to the deterioration of insulation can be judged.
	Rectification diagnosis	Precision diagnosis	Rectification characteristic measurement device	By measuring the rectification flux distribution at the neutral point and contact characteristics of brushes, the causes of rectification defects can be analyzed by the comparison with the normal situation.
Control system diagnosis technique	Dynamic characteristics diagnosis	Precision diagnosis	Frequency characteristics measurement device	A signal which does not affect the product quality is imposed on the operating control unit, and the frequency characteristics including electric and mechanical characteristics can be measured.
		Precision diagnosis	Thyristor fail tracer	The waveform at each part during the abnormal period of thyristor control unit (mainly gate pulse) can be automatically recorded and played back.

High voltage cable diagnosis	Insulation diagnosis	Precision diagnosis	High voltage cable insulation diagnosis device	Based on the magnitude and time change of current leakage by imposing high DC current, deterioration can be judged.
Transformer diagnosis technique	Gas in oil analysis (Gas chromatograph)	Precision analysis	Analyzer of gas in oil	By analyzing quantity of flammable gas in oil, the destruction of insulation or local heat can be judged.

Predictive Maintenance Flow Diagram



Execution structure of equipment diagnosis operation



Introducing Vibration Diagnostics for Rotating Machinery

Step 1: Establish a core team by training people likely to make good vibration diagnosticians.

Step 2: Designate certain items of equipment as models for practicing vibration diagnostics. Core team members practice their skills on this equipment and then pass on their knowledge to others.

Step 3: Designate certain items of equipment within each workplace as models for implementing vibration diagnostics. In process industries, feed pumps or gas compressors are probably the most suitable types of equipment for this, as their operating conditions and the properties if the materials they handle are fairly stable.

Step 4: Set provisional periods and criteria for measuring the vibration of the model equipment. To begin with, set periods of approximately one month, two months, or three months.

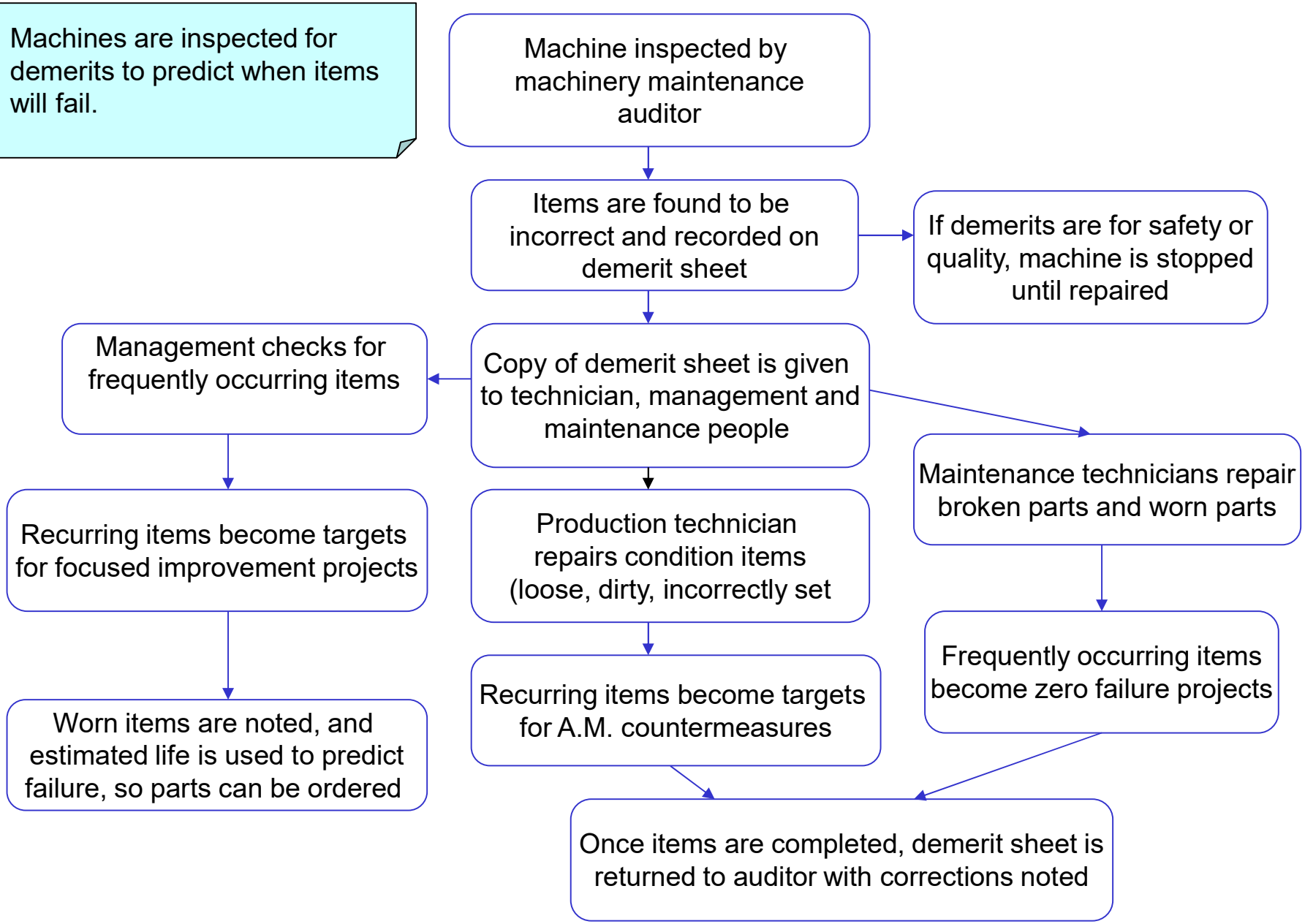
step 5: Monitor the model equipment intensively for the set period. When a large degree of dispersion occurs in the measurements, check the state or the measuring surface to find out whether the measuring point moved or the attachment pressure of the measuring instrument changed. Also check whether the machine's load has changed, the machine's rotation rate has varied, or the machine is resonating. Then repeat the measurements.

Step 6: Have the core team meet to discuss the diagnostic techniques and results. Prepare case-study materials and use these for training.

Step 7: Establish a comprehensive diagnostic system, perform diagnostic measurements, analyze and collate the results, and disseminate the technique throughout the organization.

Develop Predictive Maintenance

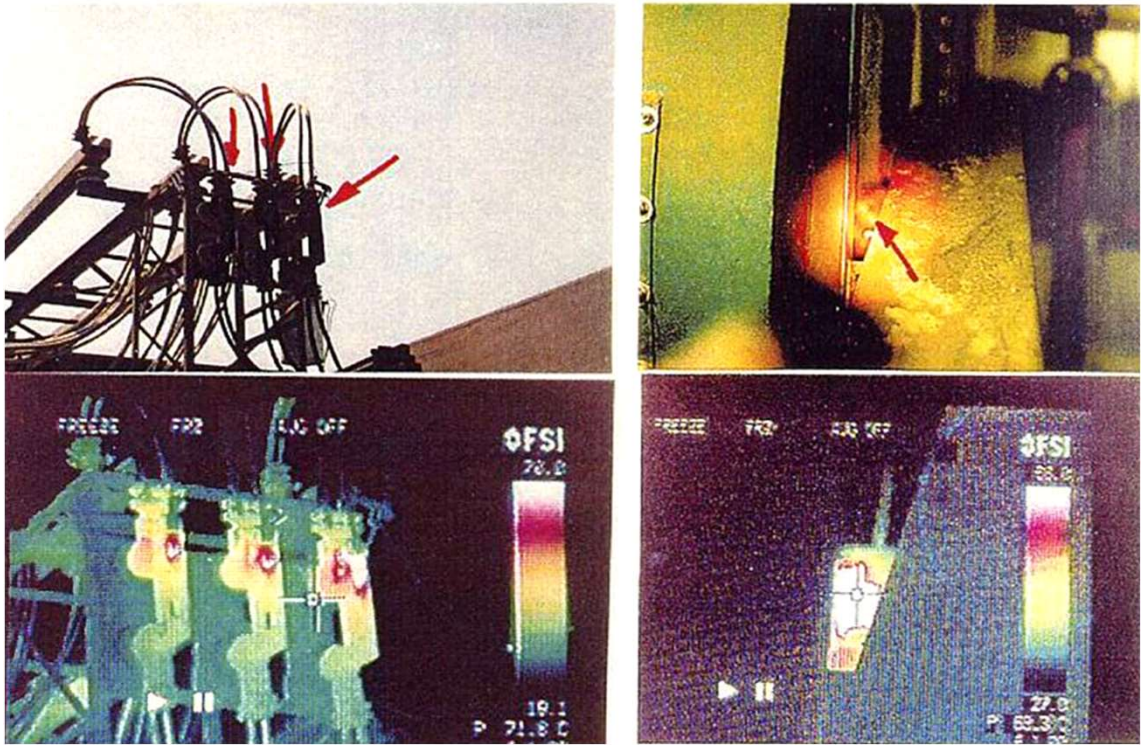
Machines are inspected for demerits to predict when items will fail.



Develop Predictive Maintenance

Infrared analysis

- Once a year, conduct an infrared analysis scan of all the major electrical equipment.
- Many of the circuits cannot be checked safely.
- Problems were only discovered after failure.
- Infrared allows failures to be avoided.
- Infrared allows for the safe inspection of circuits.



Develop Predictive Maintenance

Predictive maintenance can be addressed by the purchase of vibration monitoring equipment.

- Training is needed as to the use of the monitor and what to do with the results.

- Infrared temperature monitoring and video imaging should be in place.

- Ultrasonic detection is used as needed, but cycles need to be developed.

- Oil analysis schedules to insure gearbox quality should be introduced, improved and amended as needed.

6. Spare Parts Management

6.1 Concept of Spare Parts Management

6.2 Seven Steps for Spare Parts Management

Concept of Spare Parts Management

In order to help P.M.,

* What spare parts to store?

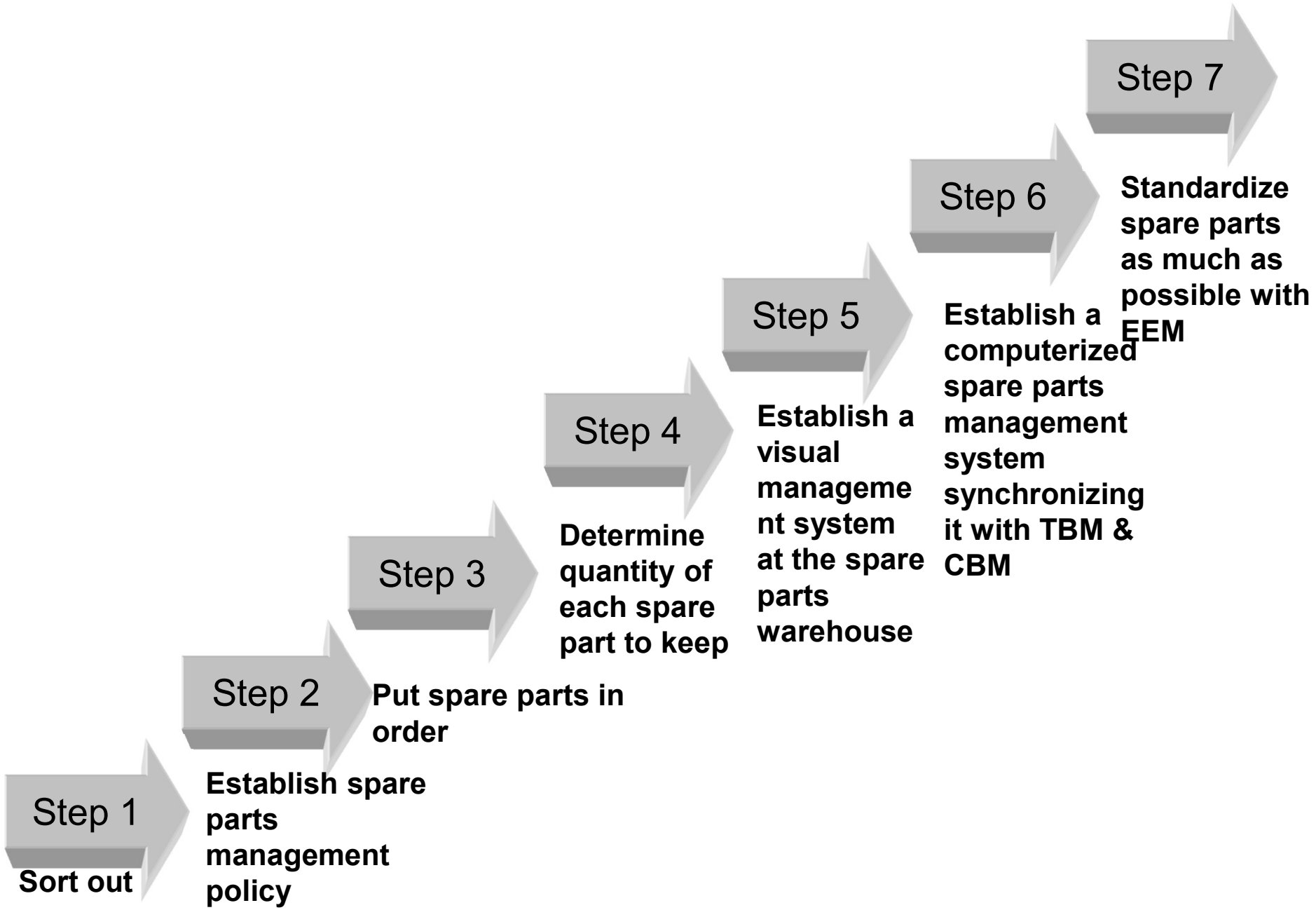
* How much?

* What control?

** Purchasing --- reordering point, EOQ, period, replenishing point

** Warehouse --- visual management

Seven Steps for Spare Parts Management



Seven Steps for Spare Parts Management (2)

Step 1	1. Sort out the necessary and the unnecessary 2. Keep the warehouse dust free
Step 2	1. Establish a policy for spare parts management and classify them into different classes
Step 3	1. Determine places to store spare parts 2. Determine the layout of the shelves for spare parts
Step 4	1. Determine those spare parts to keep and replenishing methods 2. Determine quantity of each spare part to keep

Step 5	1. A drawing of the layout is affixed to make understandable at sight the localization of parts and contents of shelves. 2. To understand at sight which parts are out of stock, which ones have been ordered. 3. To avoid mixing up of parts : pictures, drawings, etc. 4. Set the reordering point so everybody can see.
Step 6	1. Purchase spare parts when needed by synchronizing with TBM & CBM.
Step 7 Recyclable : motors, gear boxes, . . . Consumable : oil, grease, seals, . . . Available in the market : sensors, limit switches, . . .	1. At the time of equipment design 2. At the time of equipment installation 3. At the time of corrective maintenance

ポンプ
リミットSW
イクロSW
トランプ
SW

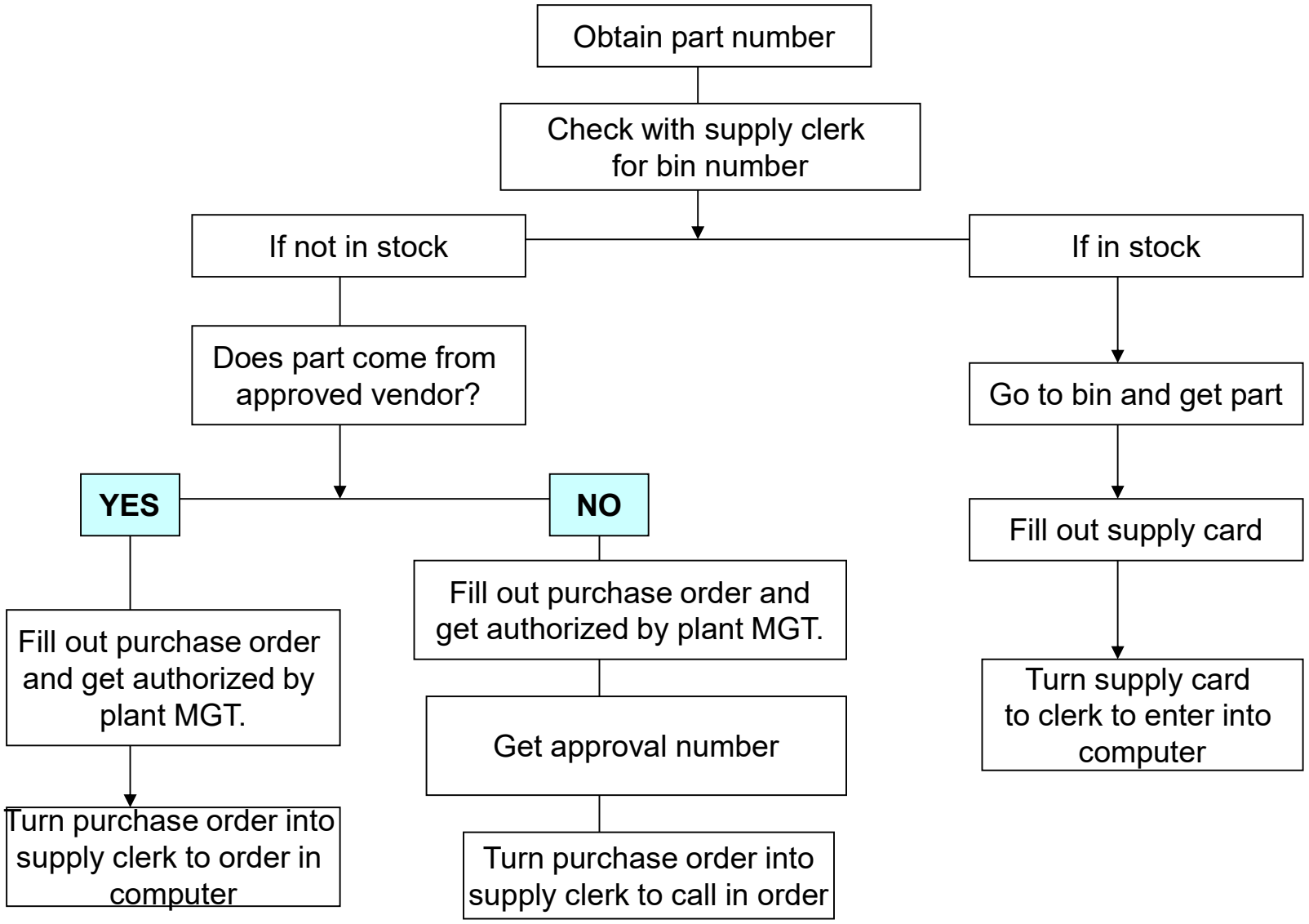
Name	V-belt		Number	B-80	
Order point	Two		Order quantity	Four	
Supplier	Webster toolshop	Unit price	JY 588	Storage location	Power maintenance spare-part store
Average demand	6/month	Procure-ment lead time	1 day	Place of use	A 1 - 8 D 1 - 5
Past problems					
Stretching occurs if stored for too long					

Also describe past quality problems so anyone can see them at a glance

Figure. Spare-Part Kanban

Spare parts management

Establish spare parts criteria



Spare parts management

Select needed and not needed parts

- Stock high wear items, such as belts, bearings, pulleys and shafts in the supply room.

- When an item is checked out of the supply room, a laser scanner reads a barcode with the part information on it.

- The barcode is scanned.

- The quantity is entered.

- The information is downloaded into a supply computer system once per day.

Spare parts management

If a part goes past a 3 months period without being checked out, the computer flags the item for review.

The item is then reviewed to see if it is still necessary to stock this part in the supply room.

This ensures that surplus inventory of unused or unnecessary parts is removed on a periodic basis.

Spare parts management

Decide storage places and quantities

Store high use parts in the supply room.

Let the computer automatically order items when the reorder point is reached.

Spare parts management

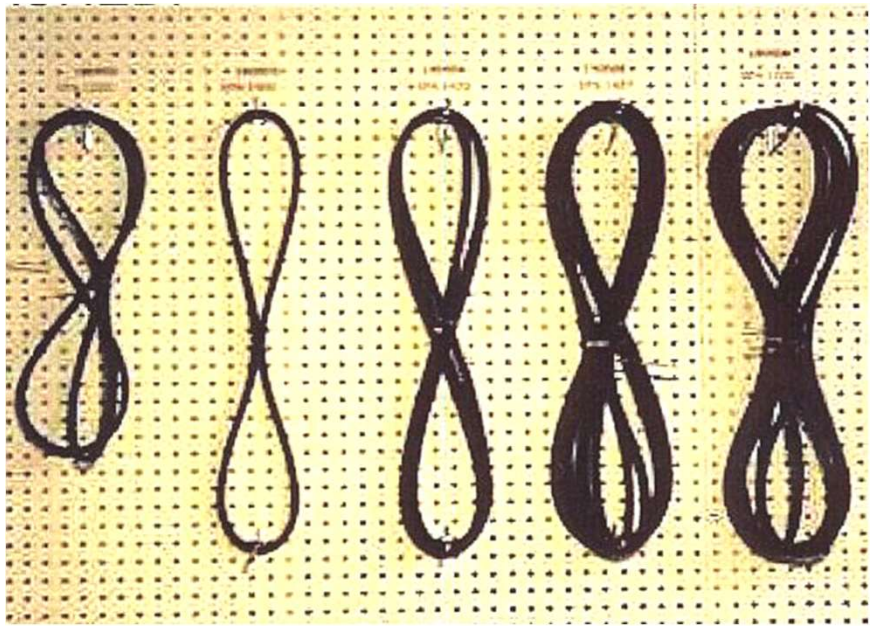
Decide storage places and quantities

Store common bolts and nuts in cabinets.

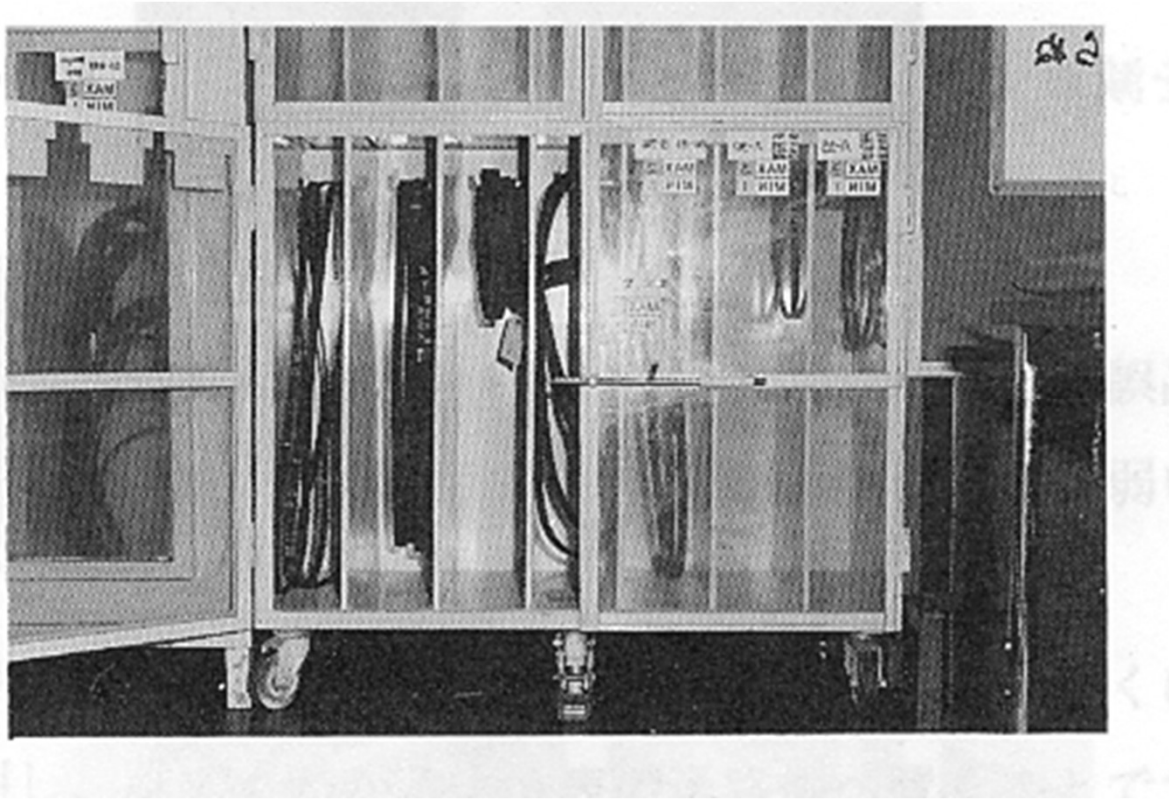
Inspect these on a regular interval and refill as needed.

Spare parts management

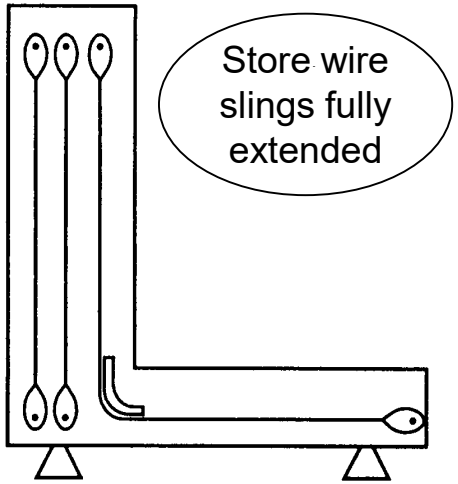
Decide storage places and quantities



Store change parts like belts on the walls.

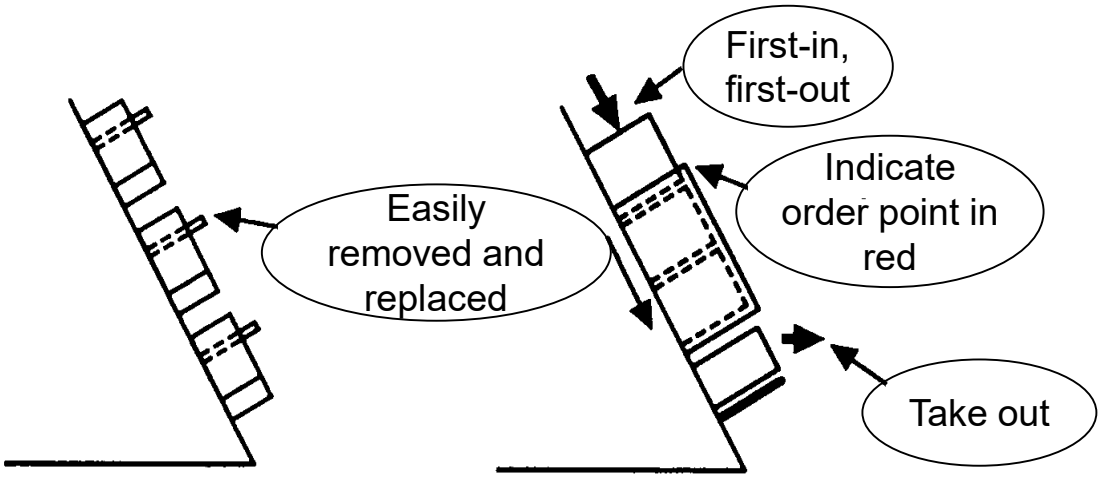


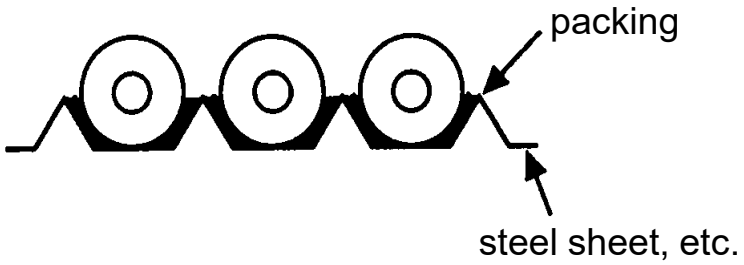
Wire slings



Examples of ideas for placing things

Place on pegs





No bumping

For small objects, use corrugated plastic sheet

Figure

7. Maintenance Cost Management and Maintenance Management System

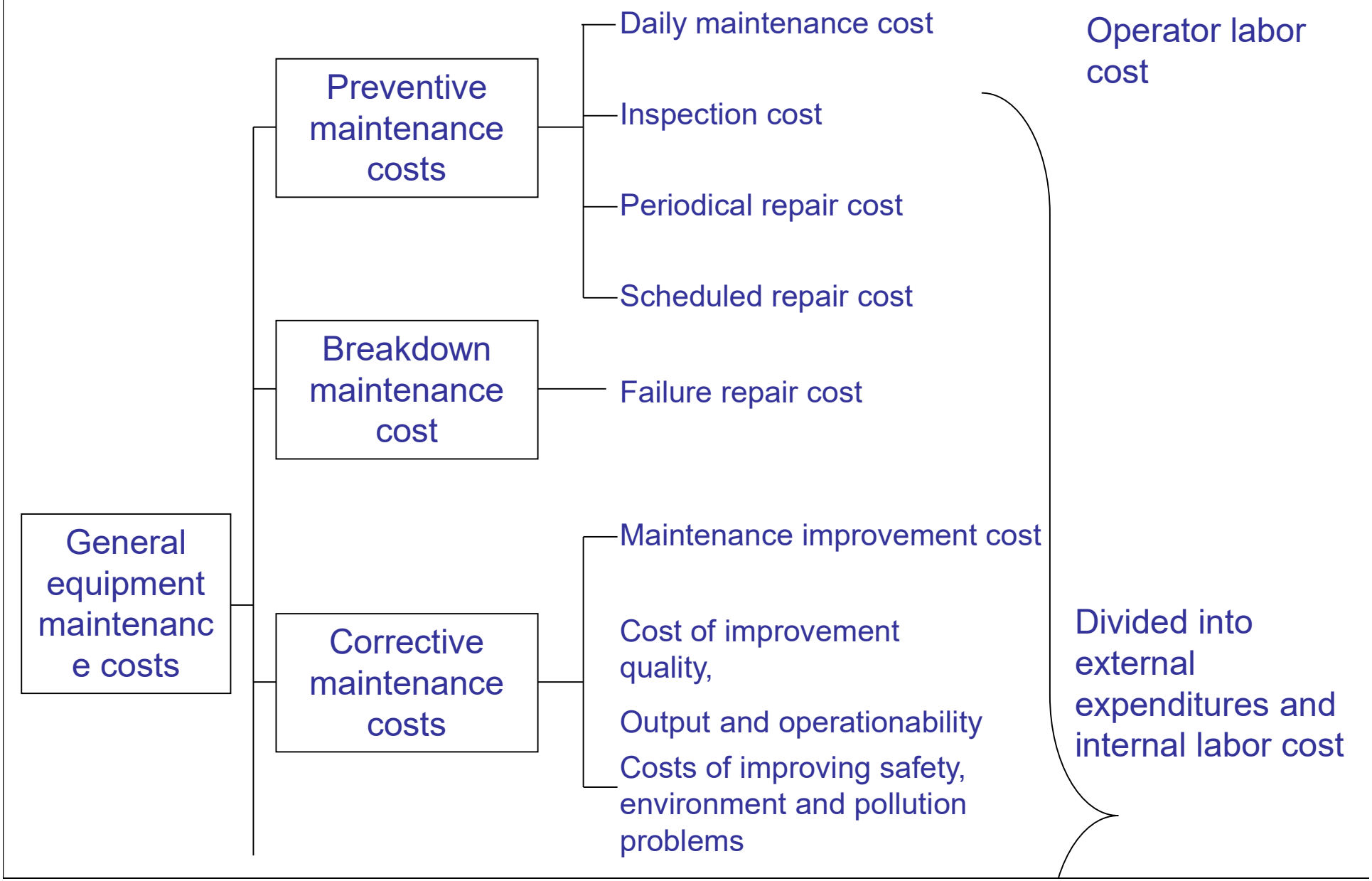
7.1 Various Maintenance Costs (Example)

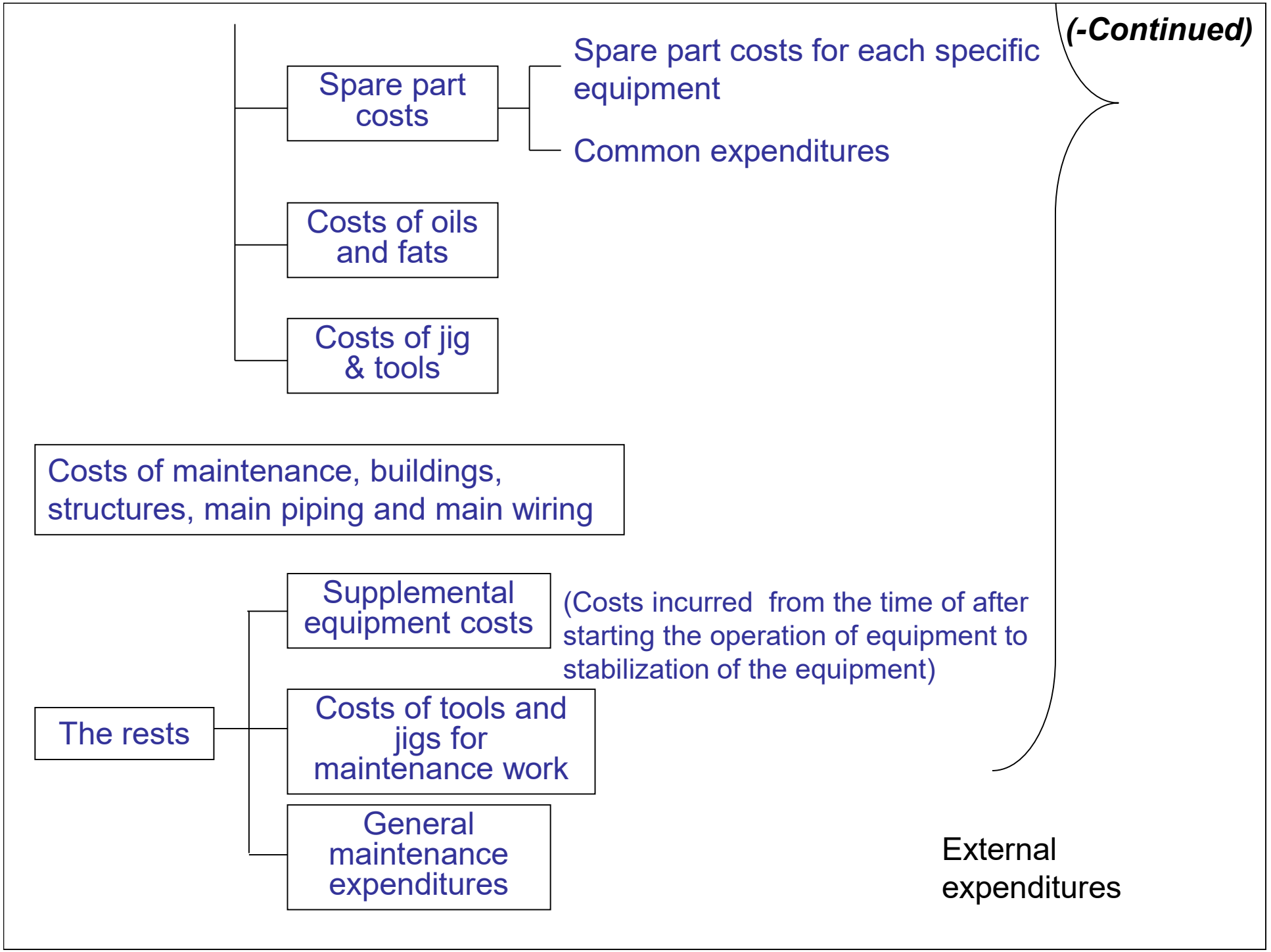
7.2 Maintenance Cost Reduction

7.3 Maintenance Management System (Example)

7.4 From Management Policy to Cost Management

Various Maintenance Costs (Example)




(-Continued)
Spare part costs
Spare part costs for each specific equipment
Common expenditures
Costs of oils and fats
Costs of jig & tools
Costs of maintenance, buildings, structures, main piping and main wiring
The rests
Supplemental equipment costs
(Costs incurred from the time of after starting the operation of equipment to stabilization of the equipment)
Costs of tools and jigs for maintenance work
General maintenance expenditures
External expenditures

Maintenance Cost Reduction

1) Review of periodic inspection / check checking cycles

- Reduction of maintenance activities

- Extension of cycles by lengthening the life spans of parts
- Extension of overhaul cycles which are determined by the shortest life part of equipment - local maintenance
- From time based maintenance to condition based maintenance

2) Is too much money spent on lubricant management? - Note that if equipment is in a normal condition, deterioration and consumption of oil are small.

3) Changes of outsourced maintenance to internal one
- Accumulation of PM technology and technique

4) Reduction of downtime loss caused by inappropriate repair and spare parts management

5) Efficiency improvement of non-standardized restoration
- Standardization of parts, establishment of the accurate datum line of parts and parts replacement system

6) Review of spare parts – Reduction of spare parts and spare parts warehouse management

(-Continued)

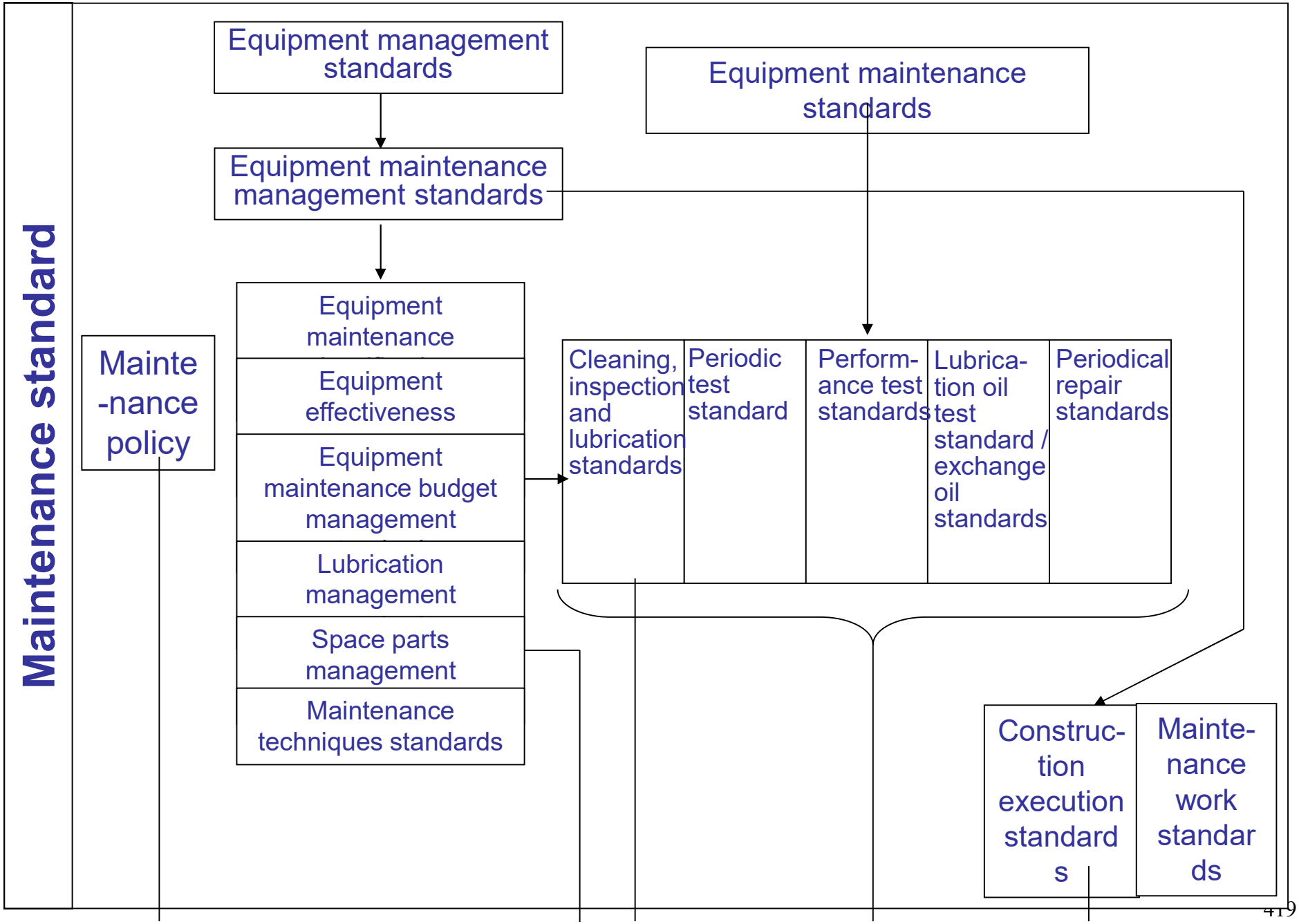
7) There are some parts which can be replaced by cheaper ones.

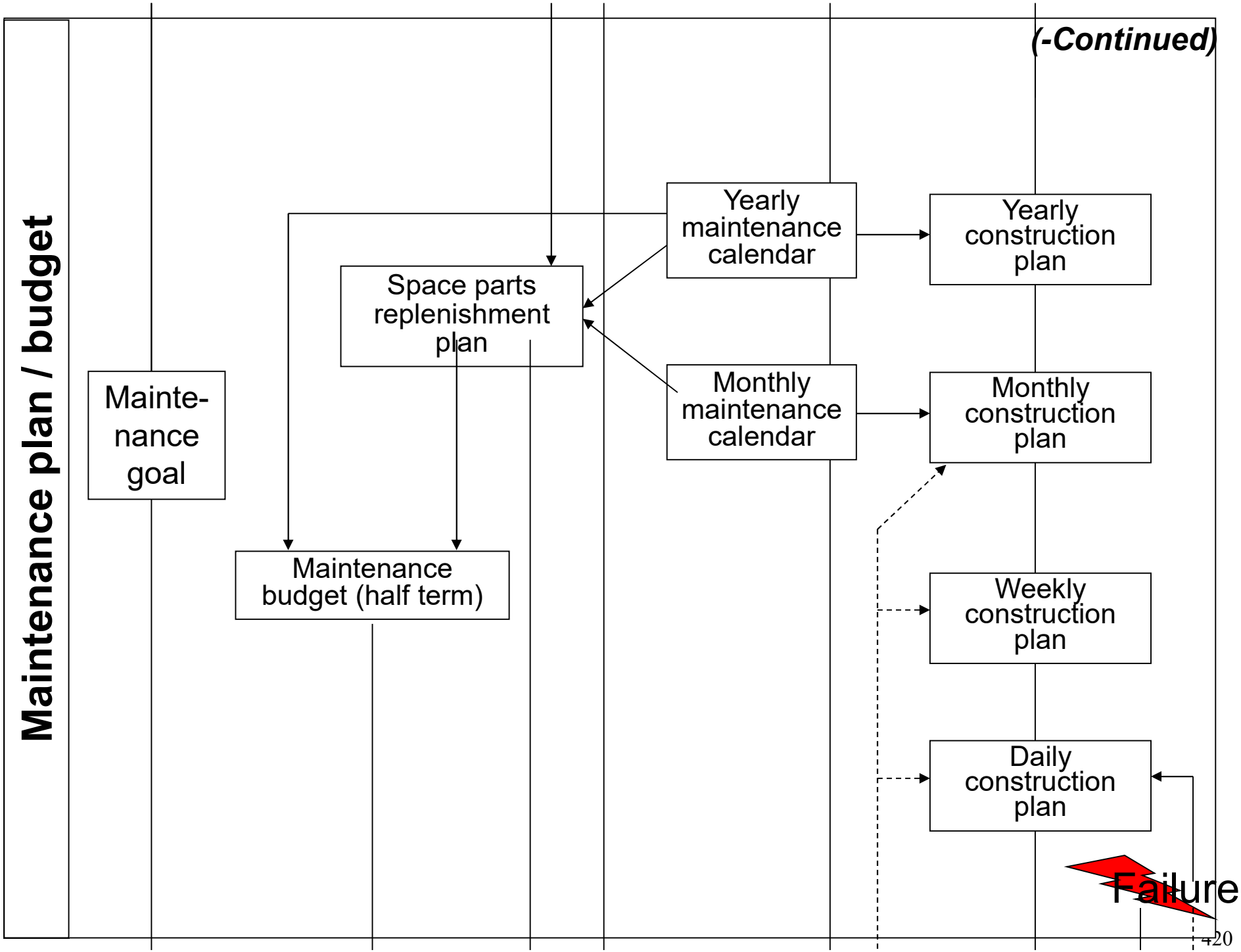
8) Effective use of unused equipment and parts
- Internal exchange of information

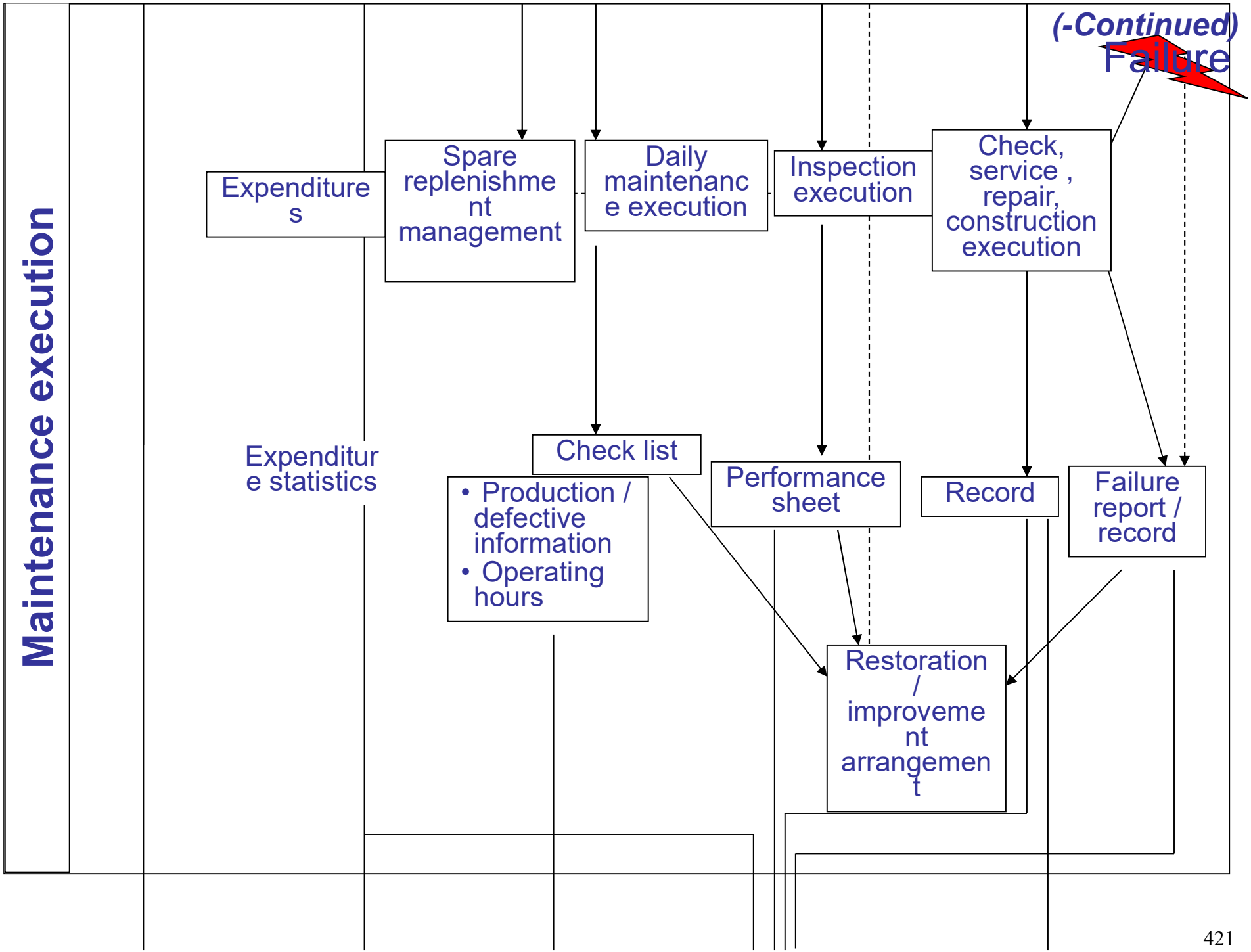
9) Reduction of energy loss - Prevention of leakage and material overflow. Prevention of idling.

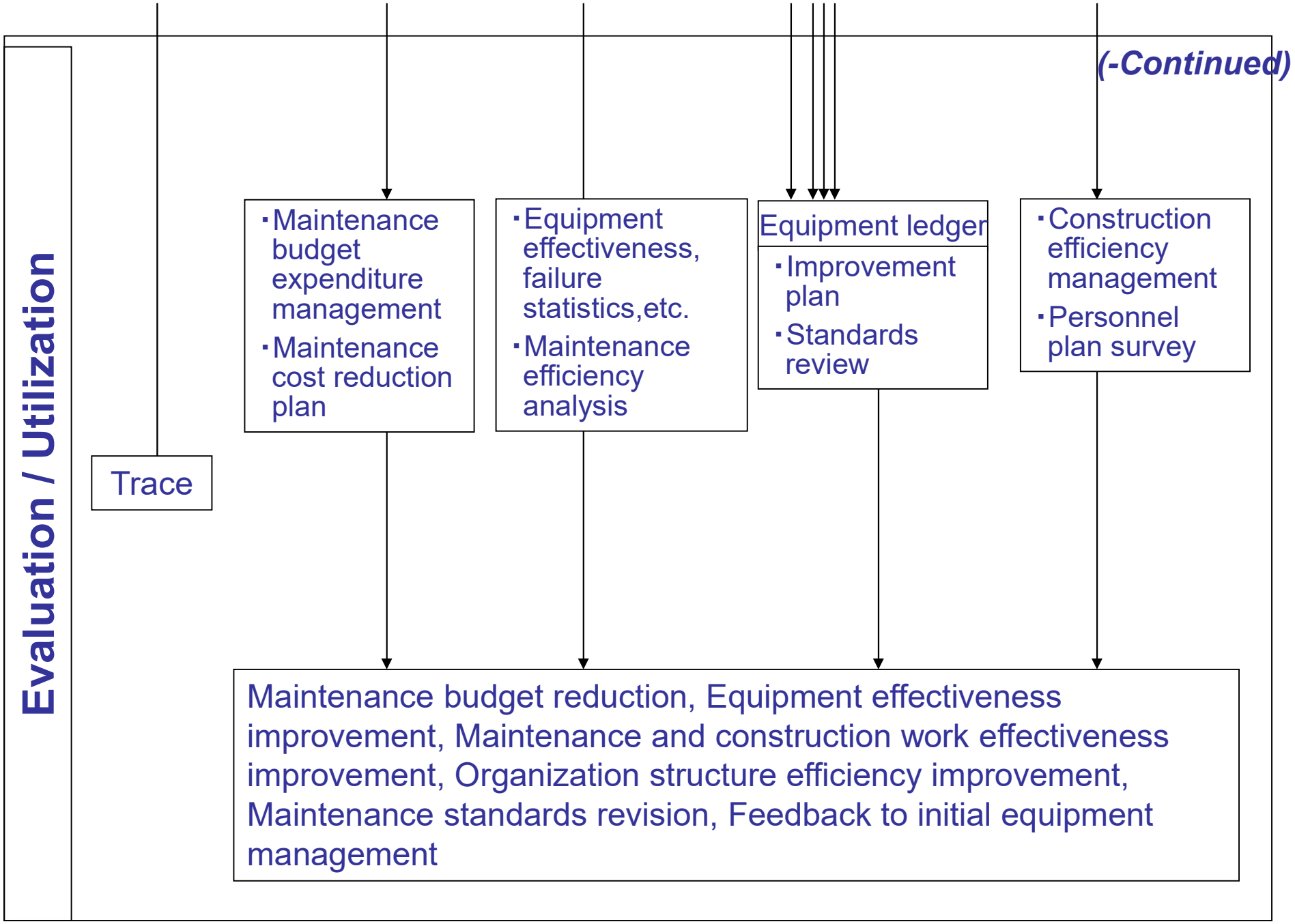
10) Removal of equipment loss
Repair of sporadic failures, reduction of yield loss
- Reduction of quality defectives by performance deterioration-type failure

Maintenance Management System (Example)




(-Continued)
Maintenance plan / budget
Mainte-nance goal
Space parts replenishment plan
Yearly maintenance calendar
Monthly maintenance calendar
Maintenance budget (half term)
Yearly construction plan
Monthly construction plan
Weekly construction plan
Daily construction plan
Failure


Maintenance execution
(-Continued)
Failure
Expenditure s
Spare replenishment management
Daily maintenance execution
Inspection execution
Check, service , repair, construction execution
Expenditure statistics
Check list
• Production / defective information
• Operating hours
Performance sheet
Record
Failure report / record
Restoration / improvement arrangement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Evaluation / Utilization
Trace
・Maintenance budget expenditure management
・Maintenance cost reduction plan
・Equipment effectiveness, failure statistics,etc.
・Maintenance efficiency analysis
Equipment ledger
・Improvement plan
・Standards review
・Construction efficiency management
・Personnel plan survey
Maintenance budget reduction, Equipment effectiveness improvement, Maintenance and construction work effectiveness improvement, Organization structure efficiency improvement, Maintenance standards revision, Feedback to initial equipment management

(-Continued)

Management policy

Management plan

Maintenance policy

Annual maintenance calendar

Production plan

Maintenance purchasing cost

Compilation of budget policy

Compilation of budget

Budget table

Name of matter	Expenditure	Budget amount	Quantity	Direct/ indirect	Division	Remarks

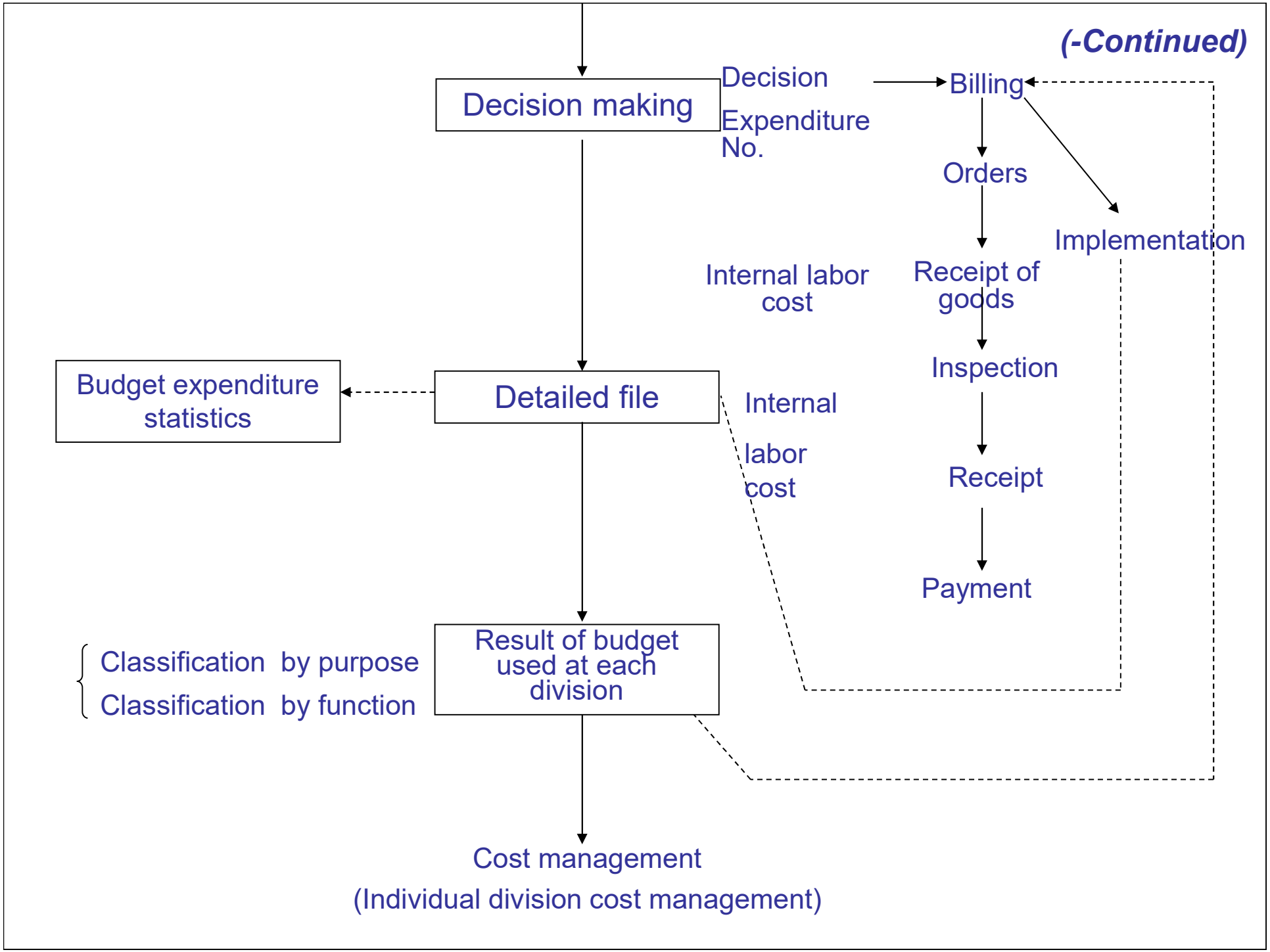
Budget request sheet

Name of matter	
Quantity	
Value	
Term	
Present condition	
Reason for request	
Technical	
Effect	

Budget discussion

Maintenance
Production
Accounting

Request for discussion making


(-Continued)
Decision making
Decision
Expenditure No.
Billing
Orders
Implementation
Internal labor cost
Receipt of goods
Inspection
Receipt
Payment
Budget expenditure statistics
Detailed file
Internal labor cost
Classification by purpose
Classification by function
Result of budget used at each division
Cost management
(Individual division cost management)

Maintenance

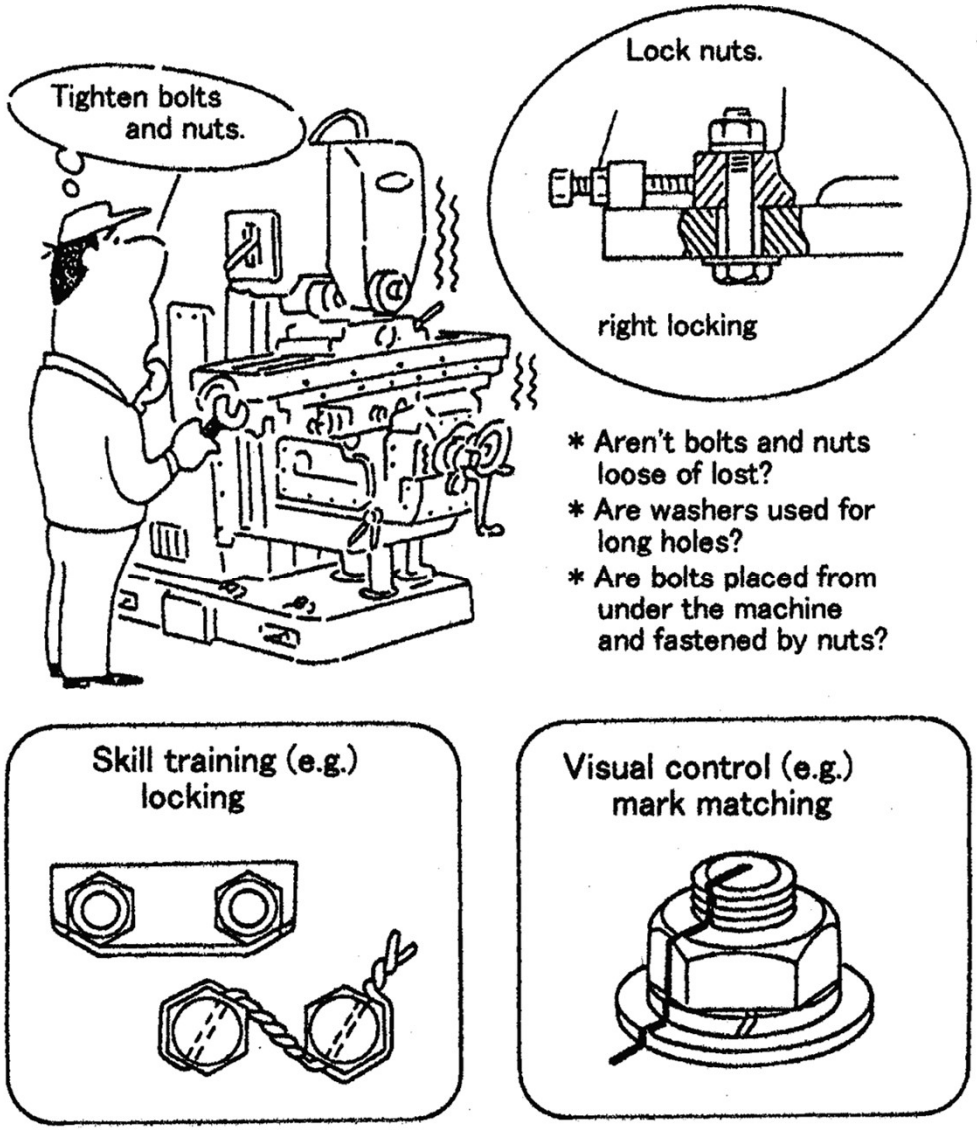
Part 1. Basic Course

Dr. H. Yamashina

Contents

Skill level
Vibration points
Bolt lengths
Are plain washers used on slots?
Anti-loosening countermeasures
Uniformity on nuts & bolts etc
Improved fasteners
Loose bolts & nuts
Bolt marking & use of spanners
Locking devices

Bolts and Nuts



Skill level

1 - Extra skill and knowledge required in order to carry out monitoring checks on bolt tightening.

Use the five senses to determine: -

a. Where all components are on the machine that are prone to vibration and stress.

b. Pinpoint these components on a drawing of the machine.

c. Check/ensure that the holding down bolts for these components have locking devises fitted.

d. Determine if these locking devices are adequate.

e. Mark all bolt heads at vibration points for monitoring checks as per drawing to determine if they have moved.

2 - Why do bolts and screws require regular monitoring? Some components on a machine are much more prone to vibration than others, such as: - motor/gearbox units, transmission drives, heavy gearing and components with heavy or uneven loading.

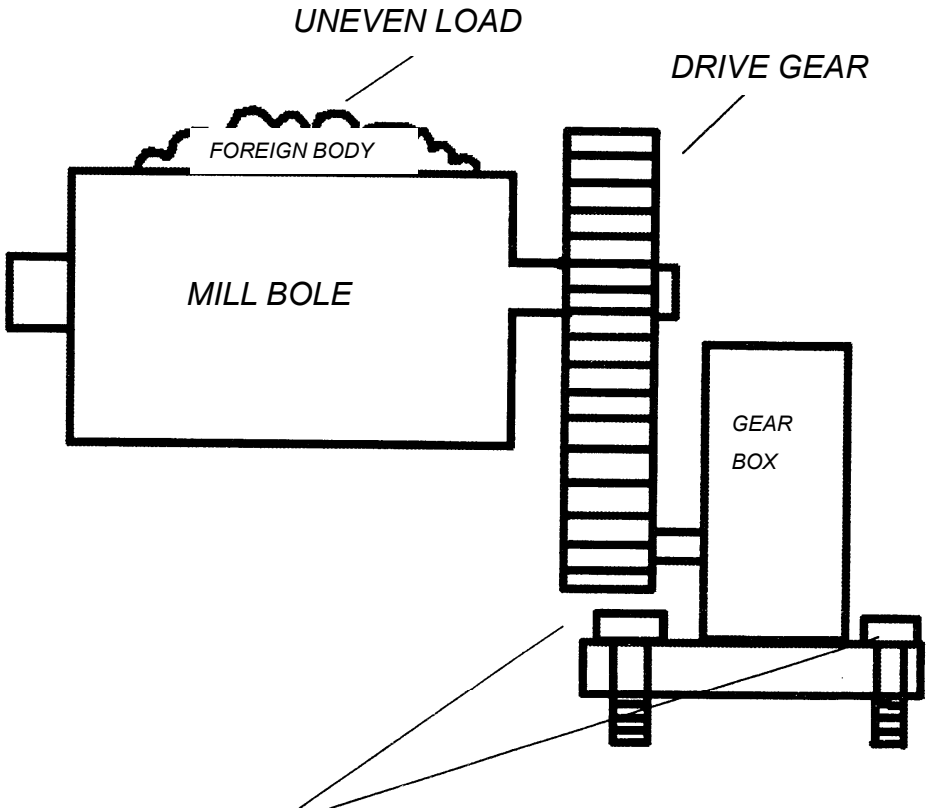
The holding down bolts on these components come under stress due to the vibration and can work themselves slack. Slack bolts can allow the component to move out of alignment. This mis-alignment will cause the machine to malfunction. Hence the need to monitor these bolts regularly.

Vibration points

3 - Check and determine where vibration points are on machine.

Bolts most under stress on a machine are the ones holding down moving parts that are subjected to uneven loading which causes vibration. This vibration is transmitted to the holding down bolts.

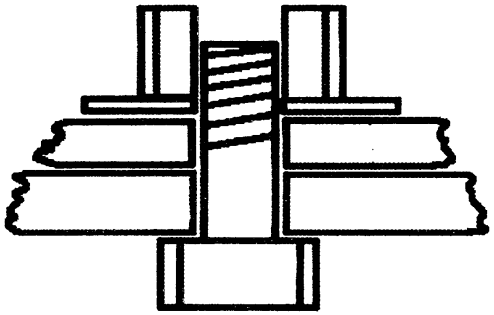
The location of these vibration points needs to be determined and pin pointed on a drawing of the machine, so they can be easily identified.



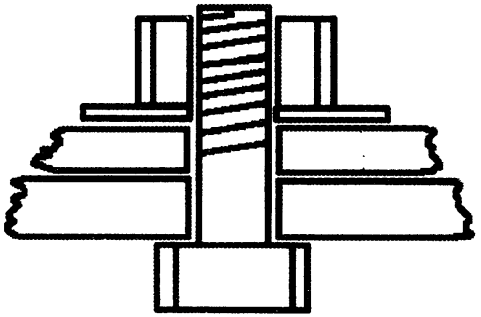
Bolt lengths

4 - Are bolt lengths adequate?

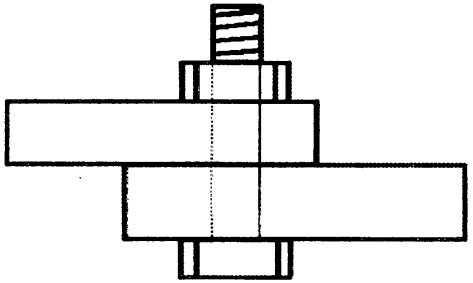
A bolt thread must always be screwed fully through the hexagon nut in order that the bolt and nut can be used to its full loading force capacity. A hexagon head screw or cap head screw need to be screwed into a thread hole to a minimum depth that is no less than the diameter of the screw.



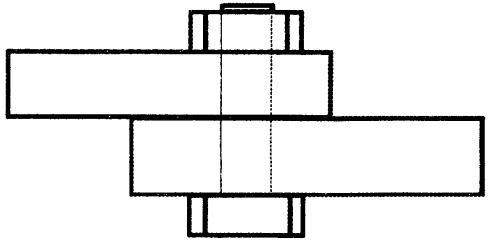
Wrong



Right



Wrong



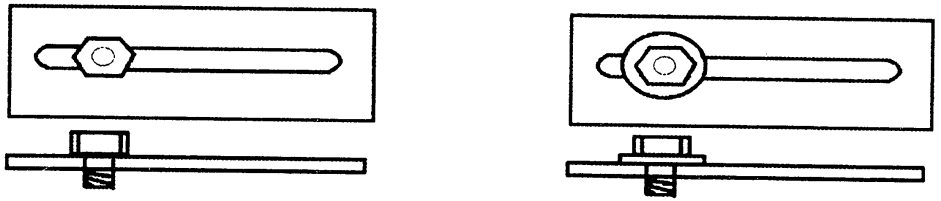
Right

5 - Are plain washers used on slots?

Slots or elongated holes are used where tension adjustment or movement for alignment are required.

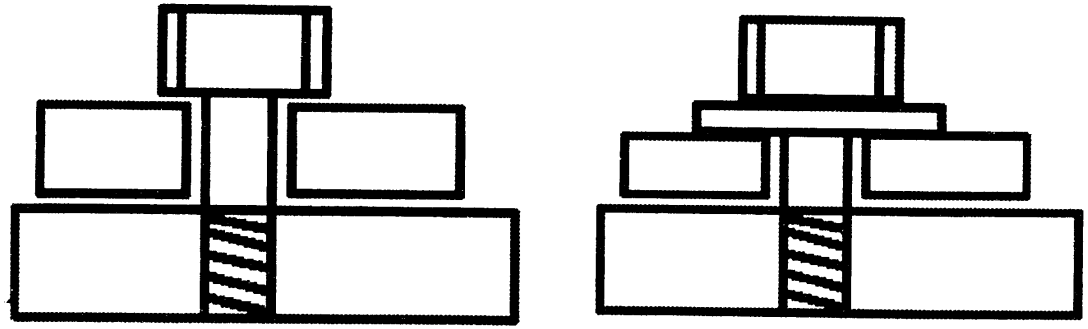
Plain washers require fitting to bolts used in these slots.

If not fitted, the nut will damage the slots when being tightened. Also the nut will not be as tightly secured due to loss of surface contact because of the slot gap.



Wrong *Right*

Where bolts are fitted into holes that are appreciably larger than the diameter of the bolt, then plain washers must be fitted so that the full surface contact of the bolt head or nut can be used.



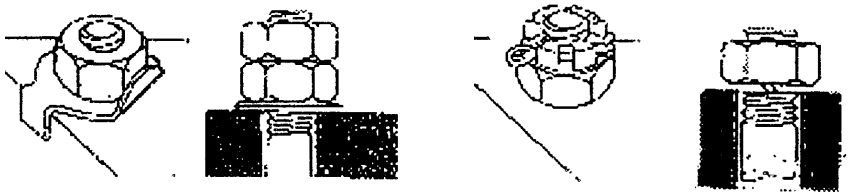
Wrong *Right*

Anti-loosening countermeasures

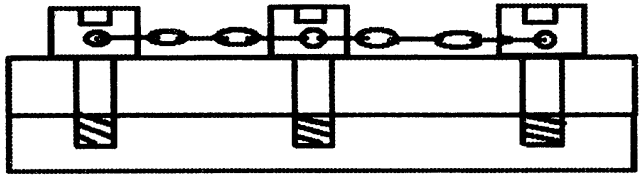
6 - Have anti-loosening countermeasures been taken where necessary?

All bolts at vibration points should have lock washers or other locking devices fitted in order to deter slackening under vibration.

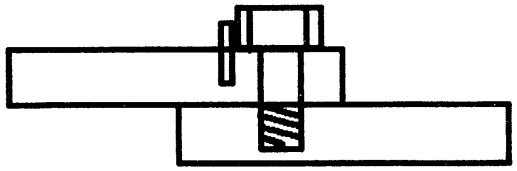
If there are no locking devices on the bolts, then make arrangements to have them fitted.



Tab lock washer *double lock nut* *Castelated nut secured with split pin* *Spring lock washer*



BOLTS WIRE LOCKED TOGETHER



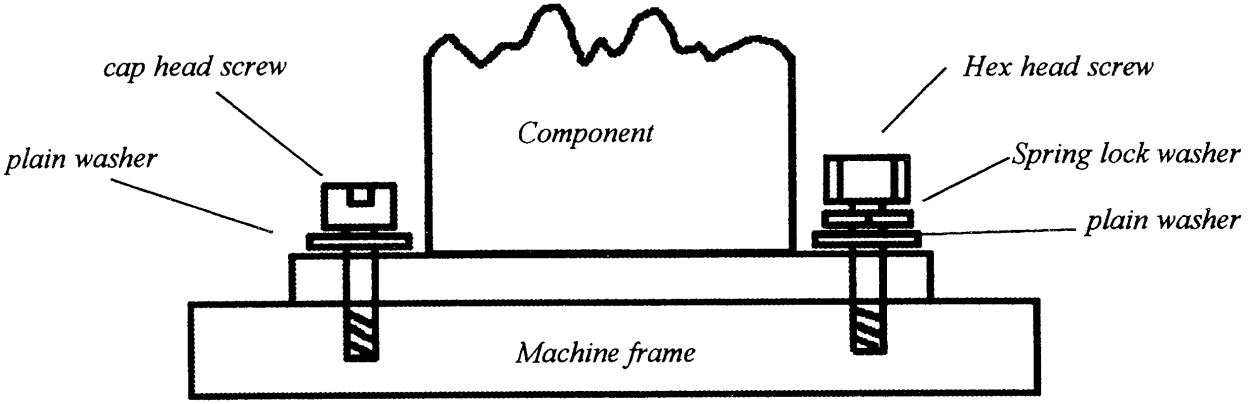
PIN FITTED AGAINST THE FLAT OF THE BOLT HEAD TO PREVENT IT TURNING

Uniformity on nuts & bolts etc

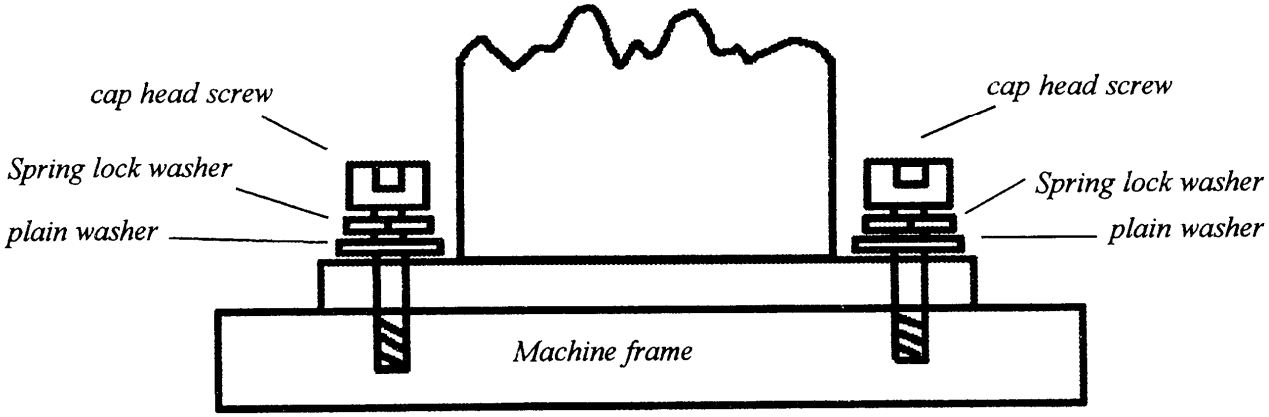
7 - Are uniform bolts, nuts and washers mounted in the same place?

It is ideal if possible, to have all bolts, nuts and washers fitted to a component to be the same type and size. Then only one size of spanner is required for removal or fitting.

The size of this one type of bolt could be marked on the component for future identification.



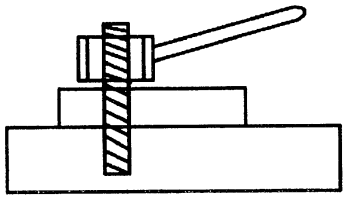
Wrong- bolts and washers different



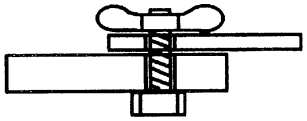
Right- bolts and washers uniform

Improved fasteners

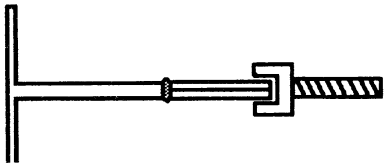
8 - Do bolts and nuts in frequently used places incorporate new ideas and improvements for fastening and removal?
Fasteners can be altered to make it quicker and easier to remove and refit equipment that is frequently being changed: -



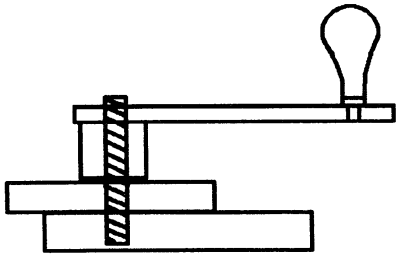
Handled
extension welded
to hexagon nut



wingnut in place
of hexagon nut.
(for light loads)



Allen key welded to
tommy bar extension



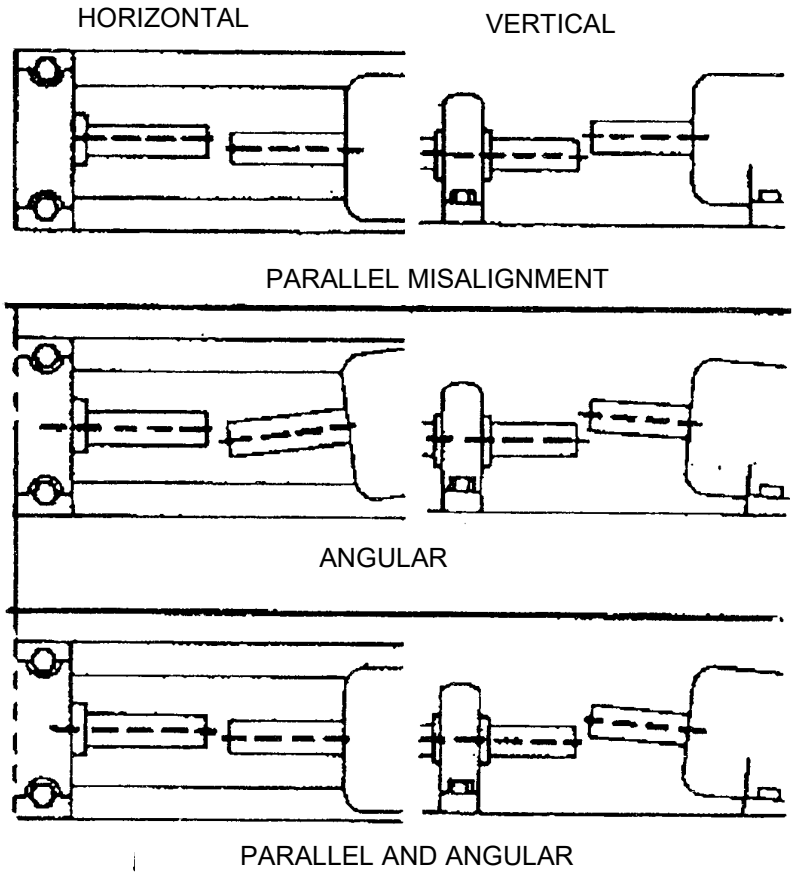
screwed nut with
extension handle

Loose bolts & nuts

8 - Check for loose bolts and nuts

All bolts on the machine require checking for correct alignment and tightened down securely, prior to marking their heads for monitoring purposes: -

a. Check and ensure that the component the Bolts are holding down is correctly aligned.



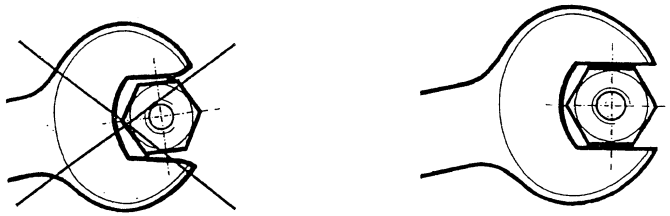
CHECKING ALIGNMENT

There are several methods of checking alignment. It may be done using a straight edge, a dial test indicator or a vernier height gauge before beginning an alignment check.

A) The mounting surfaces must be clean and flat.

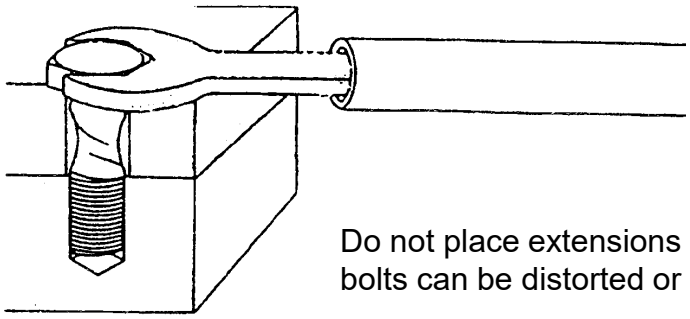
B) The mounting bolts must be tight. Alignment must be checked in both horizontal and vertical planes

b. Tighten down all the bolts using the correct size spanner and apply the appropriate pressure on the spanner to ensure they are tight.

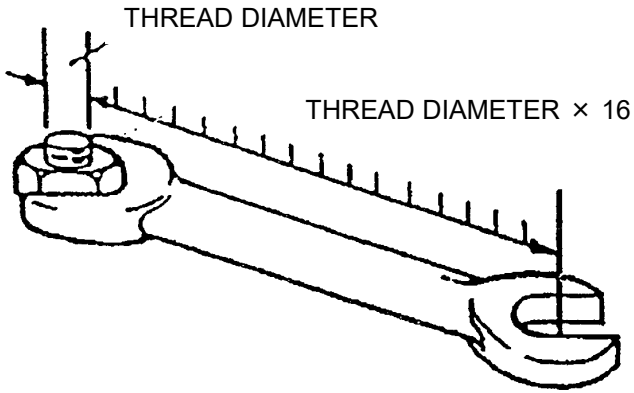


Bolt marking & use of spa

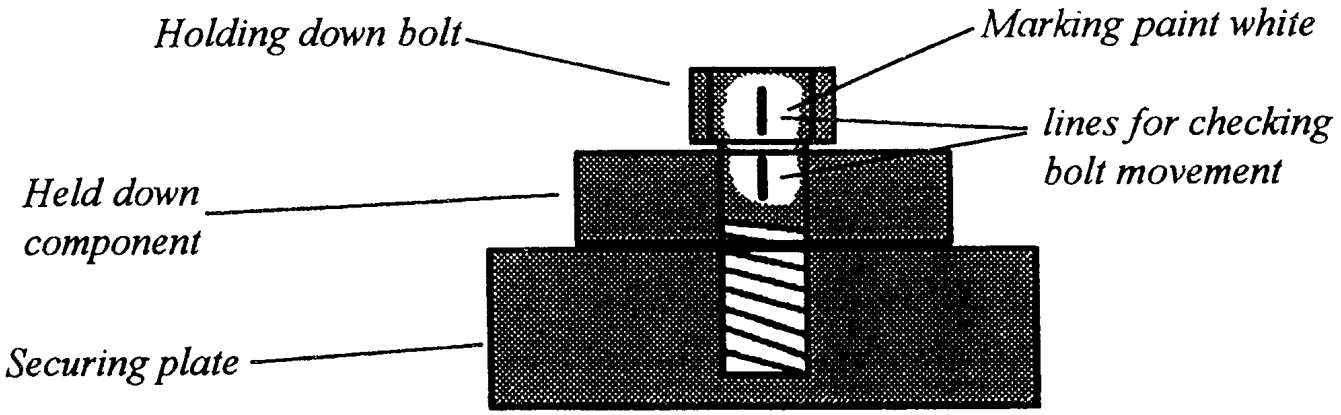
Correct use of spanners 1. The corr st always be used. A ise invariably cause damage and can be dangerous. 2. Spanners must not be lengthened by adding other tools to increase the leverage. Firm pulling pressure on spanner will create roughly 60 or 80 lbs/ft, which is generally sufficient for bolt tightness.



Do not place extensions on spanner, bolts can be distorted or broken.

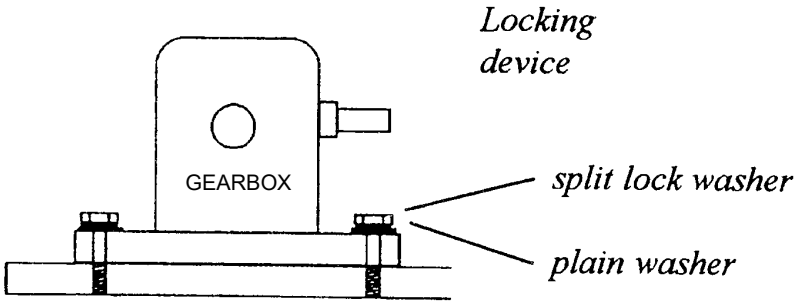


c. Mark all the heads of the bolts with a clear line. Extend this line onto the component so that a quick visual check will reveal if the bolts have slackened.



Locking devices

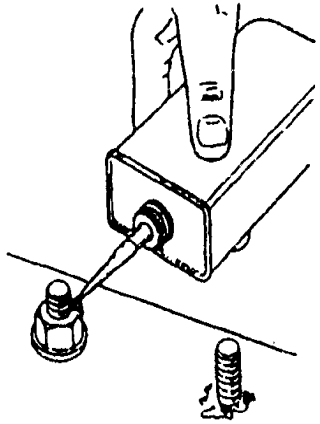
d. On components that are subjected to uneven loading which causes vibration, all the holding down bolts must have locking devices fitted.
If they do not have locking devices, ensure they are installed.



e. One exception to marking all the bolts on the machine is where daily or weekly equipment changes take place. There is no need to do these bolts.
If the equipment change takes place monthly then it is questionable whether the bolts are marked or not.

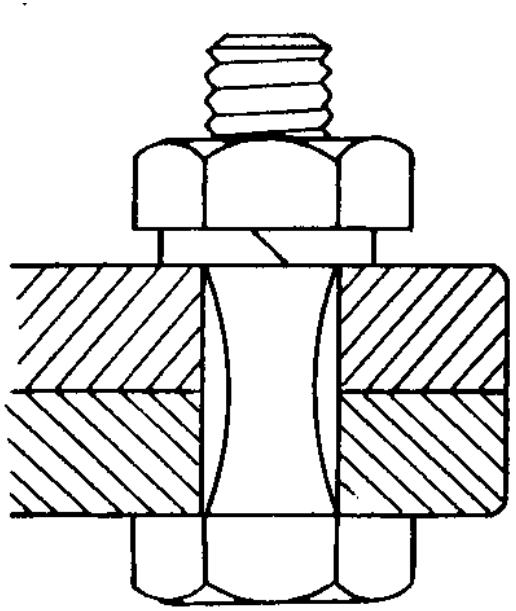
d. Any damaged bolts that you come across must be renewed.
Seized bolts can be eased by soaking with plus gas penetration oil.
If the bolts still refuse to budge report to the Maintenance Department.

Rusted and seized nuts and studs can be e / to the stubborn item and allow to soak for about 5 – 10 minutes. The nut or stud s

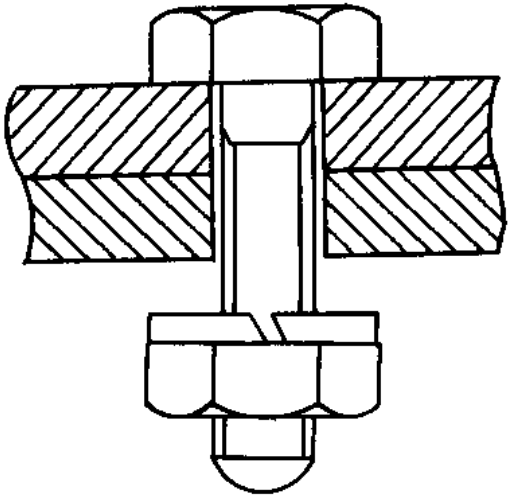


Don't fasten bolts/nuts too tight!

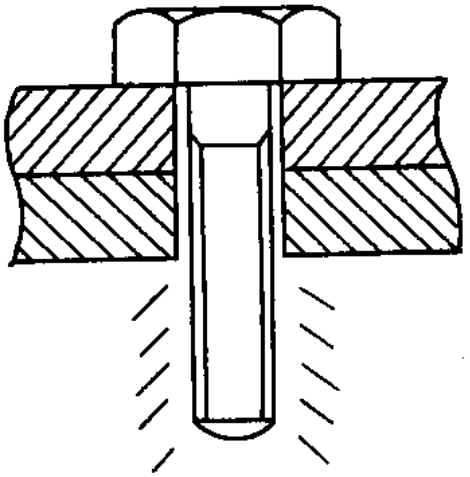
If tightened too much, bolts easily get broken.



Do not insert bolts from the top!

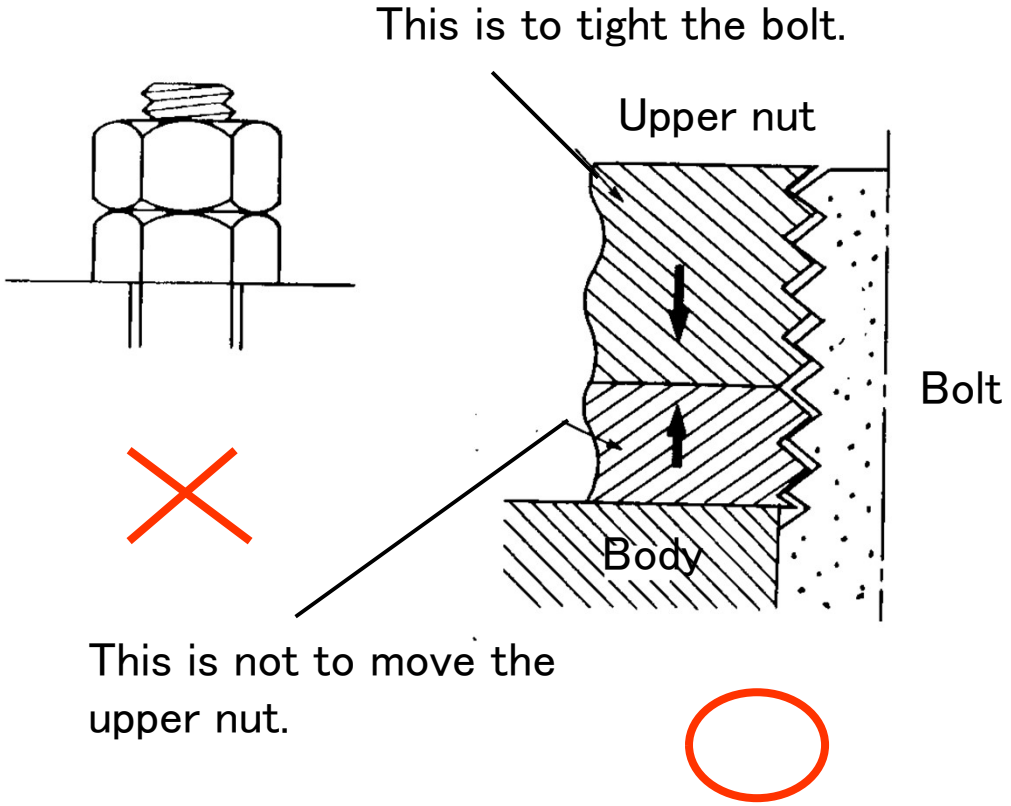


Overlook the loosened nut.



The lack of the nut cannot be found.

Do not use thinner nuts above thicker nuts!



Contents

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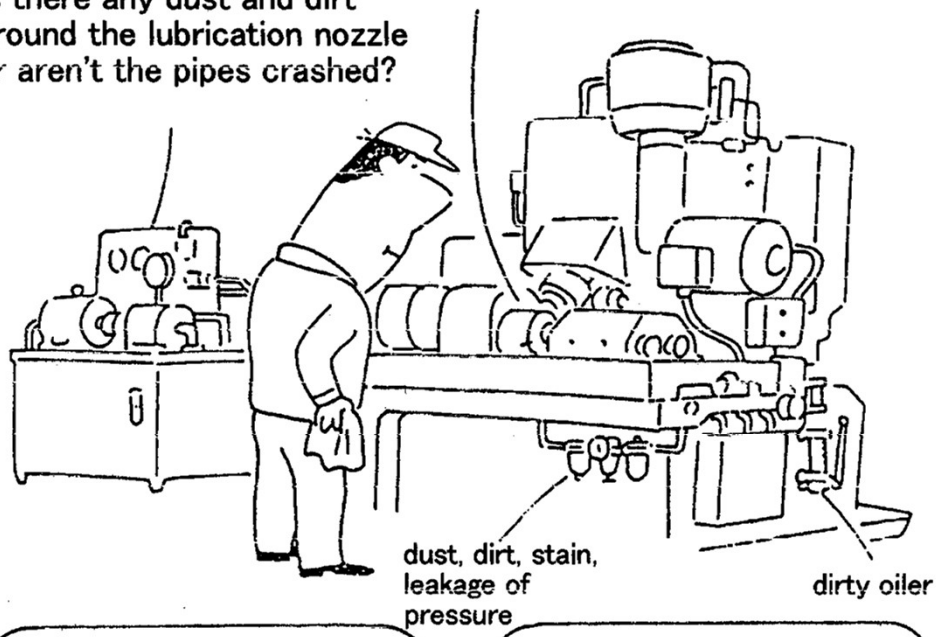
Grease Cups
Recirculatory system
Mechanical Lubrication Oil Bath
Oil mist lubrication in pneumatic circuits
Gearbox oil levels
The importance of Cleanliness
Management of lubrication stations
Lubrication points
Is correct lubricant used?
Amount of lubricant
Damage to pipes etc
Grease guns/bottles etc
Monitoring the Lubrication system
Points to consider
Fact finding

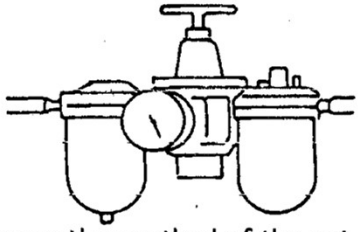
Lubrication

* Is the automatic lubrication machine working?
* Is there any dust and dirt around the lubrication nozzle or aren't the pipes crashed?

* Is lubrication enough at the rotating parts, sliding parts, chains, etc.?

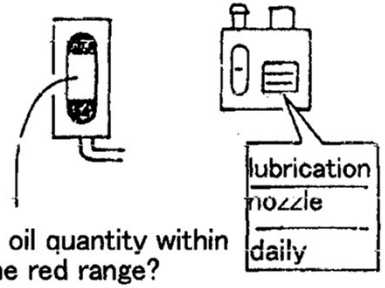


Skill training (e.g.)



Inspection method of the set of 3 air pressure devices

Visual control (e.g.)



Is oil quantity within the red range?

General Inspection

What will you be responsible for checking?

1. There is an audit sheet you will be checked against.
2. There will be extra knowledge that you will be taught to allow you to understand better the checks that you are making.

Audit Sheets

Here is a copy of the audit sheet. As you can see the checks are quite simple. We will now explain lubrication to you and then come back to this audit to help you relate what you have taught yourself to do.

		1 point	2 point	3 point	4 point	5 point	6 point
The audit (lubrication)	Do oiling places have a label correctly attached and are ideas incerperated to lubricate all places, without omission?						
	Is correct oil used?						
	Is oiling amount appropriate?						
	Check for oil deterioration.						
	Check for oil supply pipe dogging and damage.						
	Is oil to be supplied always available?						
	Are and oil lubricators managed for each of type?						
	Check for damage and attached dust and dirt on and nipples.						
	Are oil stations managed for each of type and are they always covered? Check for attached dust and dirt on them and their pollutions.						

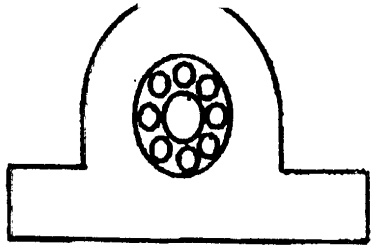
Skill level

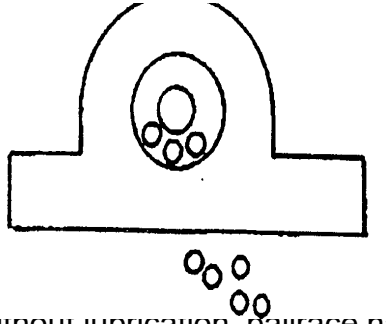
Extra skill and knowledge will be required in order to carry out monitoring checks on lubrication systems.

a. Understand the function of the lubrication system on his machine.
b. Have knowledge and understanding of components used on a lubrication system.
c. Determine the location of pressure, temperature and level indicators in the lubrication system.
d. Decide which points in the lubrication system are most vulnerable to leakage, blockage and wear.
e. Create an inspection check for monitoring the lubrication system on his machine.

Function of a Lubrication System

Moving parts on a machine will deteriorate and rapidly fail in production if they are not lubricated at regular at intervals for the rest of their working life.





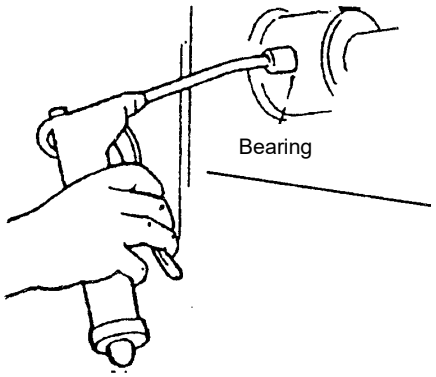
ıtc.

ion

without lubrication, ballrace has collapsed

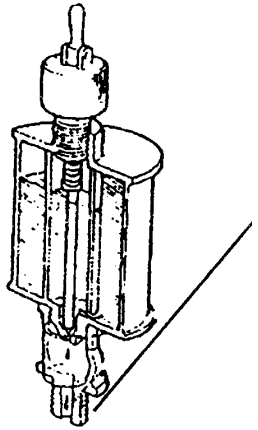
A lubrication system allows lubricant to be fed to these moving parts to keep them operating to their optimum level of performance.
The lubricant can be fed to the moving part in various ways.

A/ by hand



Hand Grease Gun

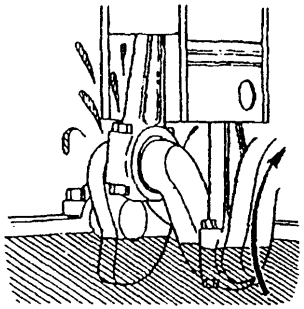
B/ by drip feed



Controlled drip feed onto bearing

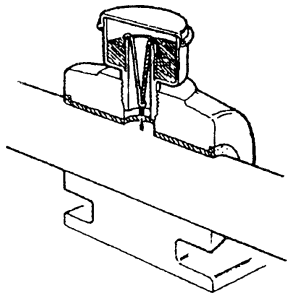
Splash Lubrication

The moving components are inside a protective housing. During operation, components dip into an oil bath and carry oil to the other components.



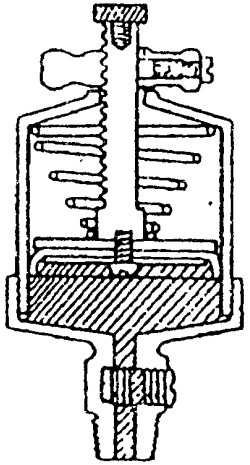
Wick feed and lubricating pads

Components requiring a low rate of oil supply are often lubricated by wick feed. One end of the wick is suspended in an ail bath and siphon action feeds oil to the part to be lubricated. Alternatively, a lubricating pad, usually of felt, is pre–soaked in oil before use and held in contact with the part to be lubricated.



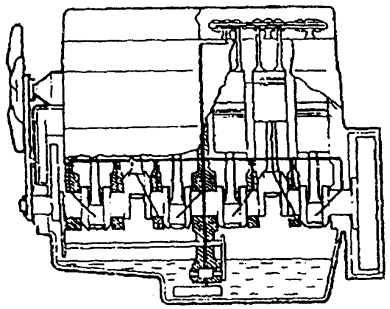
Grease Cups

Some grease lubricated bearings may be supplied with their lubricant from a grease cup. There are two distinct types: Spring operated, where grease held in the cup is continuously forced under spring pressure to the bearing. This type of cup is suitable only for the thinner grades of grease, and for short direct feed ducts or pipes.



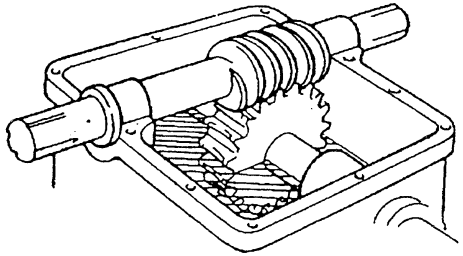
Recirculatory system

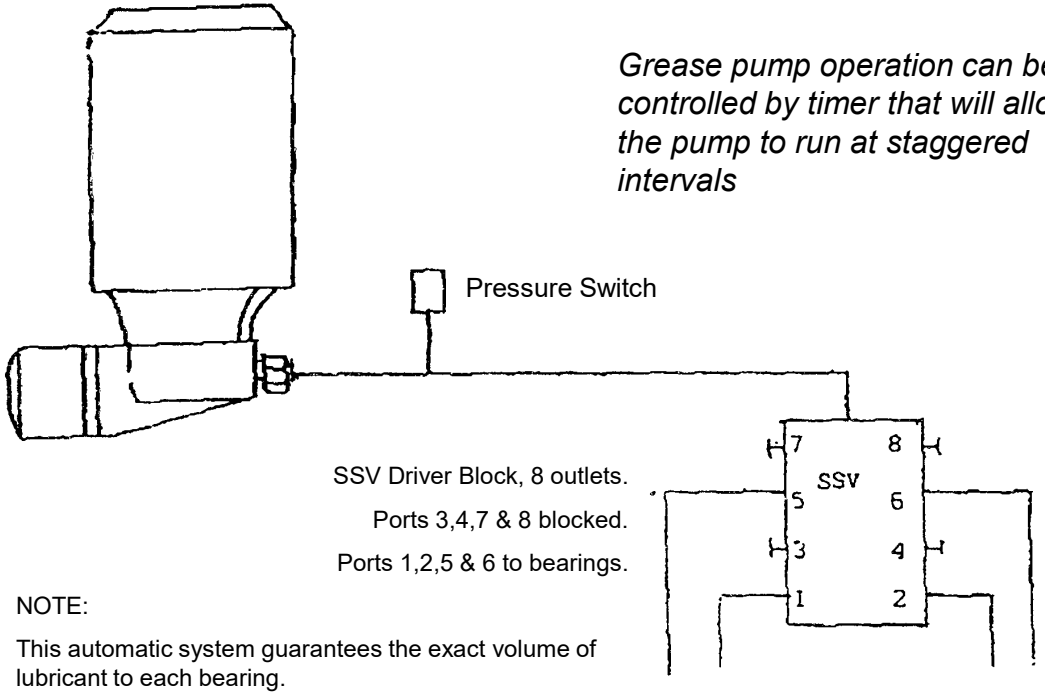
The moving components are totally enclosed in protective housing. A certain quantity of oil is contained in a sump formed by the base of the housing or in a tank. Splash lubrication is often used to lubricate other components.



Mechanical Lubrication Oil Bath

This type of lubrication will only be efficient at low speeds and may be used to lubricate such items as worm gears and gear boxes. Oil bath seals must by well maintained to prevent leakage.





Grease pump operation can be controlled by timer that will allow the pump to run at staggered intervals

SSV Driver Block, 8 outlets.

Ports 3,4,7 & 8 blocked.

Ports 1,2,5 & 6 to bearings.

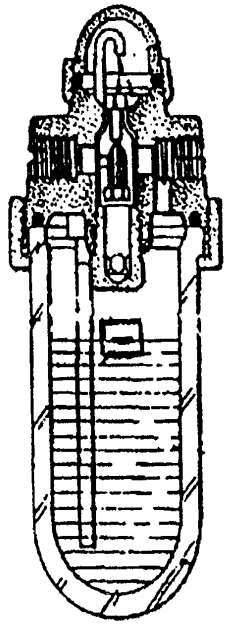
NOTE:

This automatic system guarantees the exact volume of lubricant to each bearing.

Oil mist lubrication in pneumatic circuits

The oil mist lubricator feed lubricated air to the pneumatic circuit which lubricates the inside of all the components in the circuit.

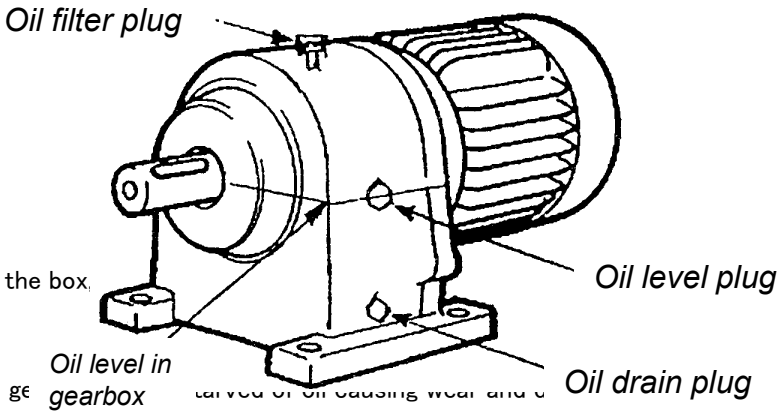
Due to venturi action caused by the flow of air, oil is raised from the bowl into a cavity beneath the dome. A small localised venturi effect causes the oil to disperse into a micro fog which enters the air stream. The unit is manually adjustable so that it may be set for a particular flow rate. At any given setting, the ratio of maximum flow rate that the unit will accommodate is 2:1.



* The level of the oil in the bowl must not drop below the pick up tube. Also the level of the oil must not be filled above the level mark on the bowl. Too high an oil level in the bowl can affect the operation of the lubricator.
* Air pressure must be removed from the air system before oil mist lubricator can be topped up with oil.
* The oil used in an oil mist lubricator bowl is Rando 32 oil. This is a thin hydraulic oil. Do not use any other type of oil other than Rando 32. Other oils will have an effect on the operation of the oil mist lubricator and could stop it from working.

Gearbox oil levels

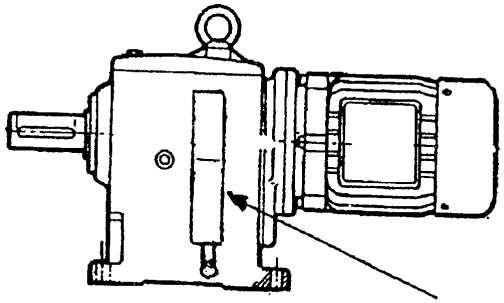
Constantly keeping the oil to a correct level inside the gearbox is vital. It will ensure that the gearbox operates to its optimum level of performance throughout its working life.



Filling a gearbox above the indicated level reduces the air space inside the box, excess oil to correct level.

If oil in the gearbox is allowed to drop to a low level components in the ge starved of oil causing wear and components.

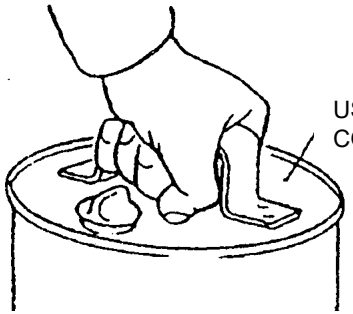
Oil level sight glasses are being fitted onto gearboxes to make it easier to determine the oil level. To obtain a true oil level in the sight glass, gearbox needs to be stopped and left for ten minutes to allow the oil in the gearbox to settle.



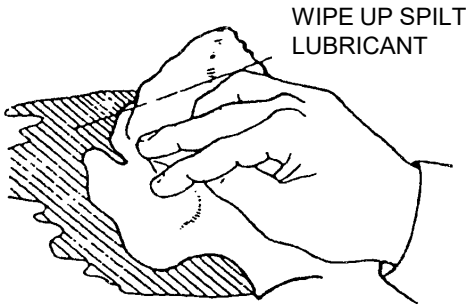
The importance of Cleanliness

Points to note

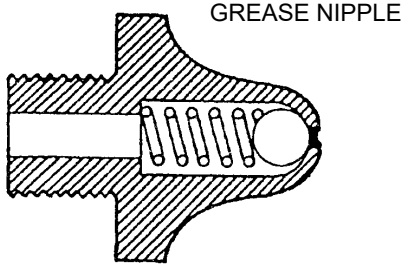
1. In lubrication system maintenance cleanliness is essential. Lubricants attract dust and grit, and dirty lubricants cause rapid wear and deterioration in machinery.
2. Lubricants should always be kept in sealed containers and only sufficient for the job in hand removed. Where possible this should be transferred straight into the machinery concerned and not left exposed to atmosphere.

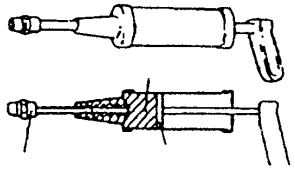


3. Ensure that excess or split oil or grease is cleaned up immediately and dirty oil waste is disposed of correctly as these are serious fire hazards.
4. Never mix different grades of lubricant. If it should be necessary to use a piece of lubricating equipment with a different grade of oil, the equipment must be thoroughly cleaned again as soon as the job is completed.

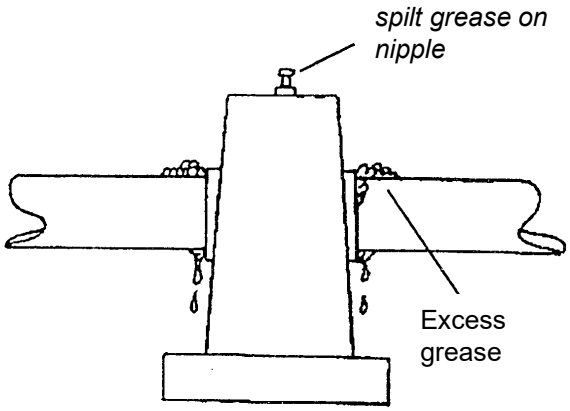


5. Ensure grease nipples are cleaned of excess grease before and after lubricating is complete.
6. Ensure coupling on end of grease gun is cleaned of excess grease before and after lubricating is complete.

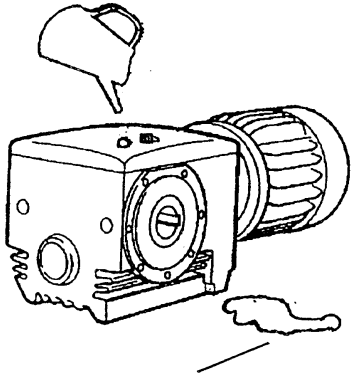




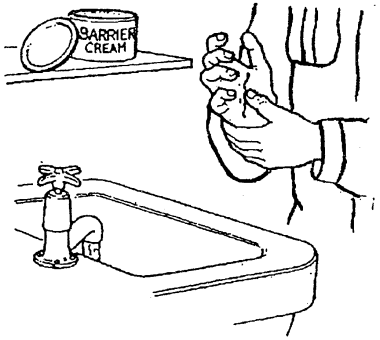
7. Ensure after lubrication that the excess grease is cleaned from bearings.



8. Clean up any oil spillage after filling the system. Lubricant spillage onto floor is a safety hazard. It is very slippery and could easily cause an accident. Clean up with a rag, then dispose of rag – which is a fire hazard.

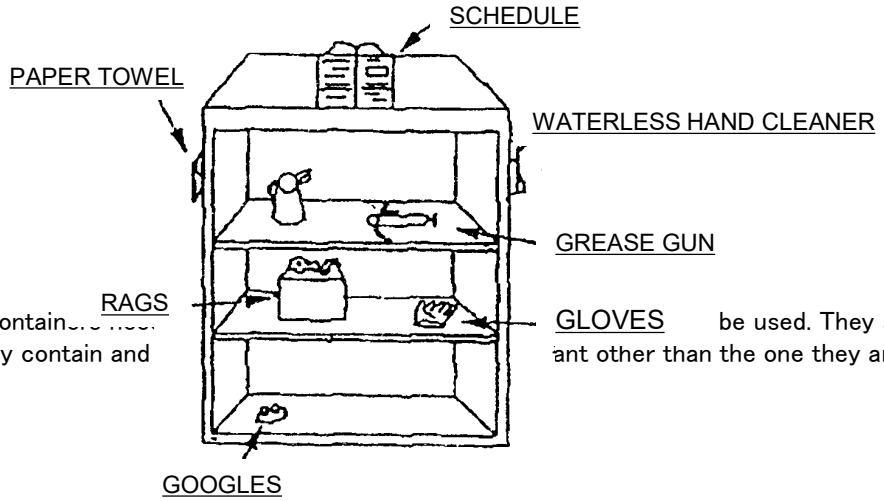


9. Use barrier cream to protect hands when working on the lubrication system. Wash hands thoroughly after completion.



Management of lubrication stations

The lubrication station is sited at the machine to provide easy access to the lubricants required for the machines lubrication schedule.

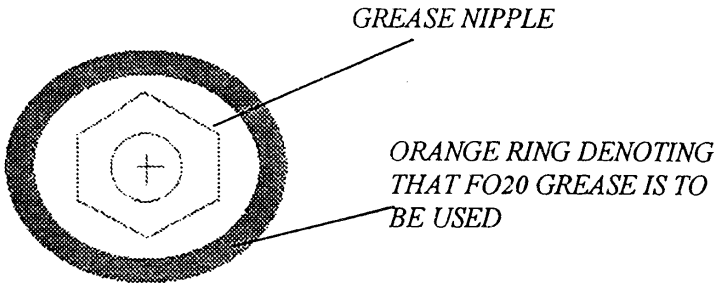


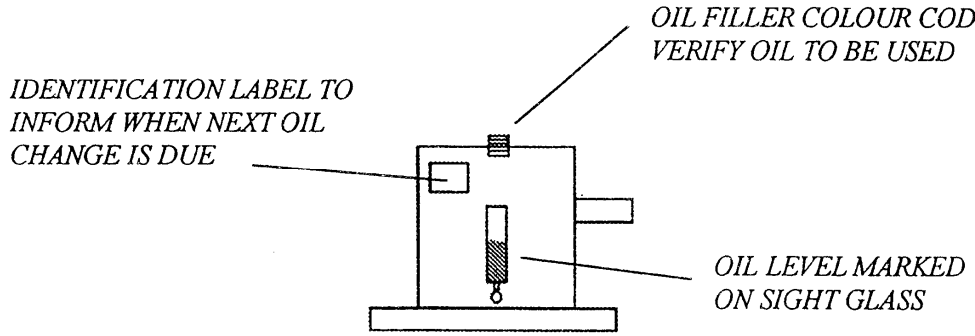
Separate hand grease guns, oil bottles and contain[illegible] be used. They should be marked and color coded clearly with the type of lubricant they contain and [illegible]ant other than the one they are marked up for.

ABBR.	LUBRICANT	COLOUR
OILS		
M220	MEROPA 220	BLACK
M460	MEROPA 460	YELLOW
T 1500	TRIBOL 1500 GEAR OIL	PURPLE
T870	TRIBOL L870	LIGHT GREEN
EP–C	GEARTEX EP–C 85W–140	DARK BLUE
GREASES		
F020	TEXANDO F020	ORANGE
TP2	TEXCLAD PREMIUM 2	PINK
N EP1	NOVATEX EP1	TURQUOISE
COUP G	COUPLING GREASE	GREY
PREM 3	MULTIFAK PREMIUM 3	WHITE
T 777	TRIBOL 777/2	DARK GREEN
TRIBOL	TRIBOL L894	RED
HYDR. OILS		
HD 32	RANDO HD32	LIGHT BLUE
HD46	RANDO HD46	BROWN

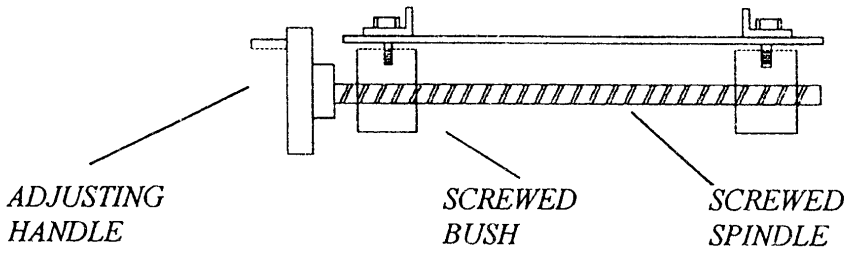
Lubrication points

Are all lubrication points on the machine correctly color coded, and are ideas incorporated to lubricate all places without omission?





Some moving p ıle or oil drip feeder. These moving parts can be ic



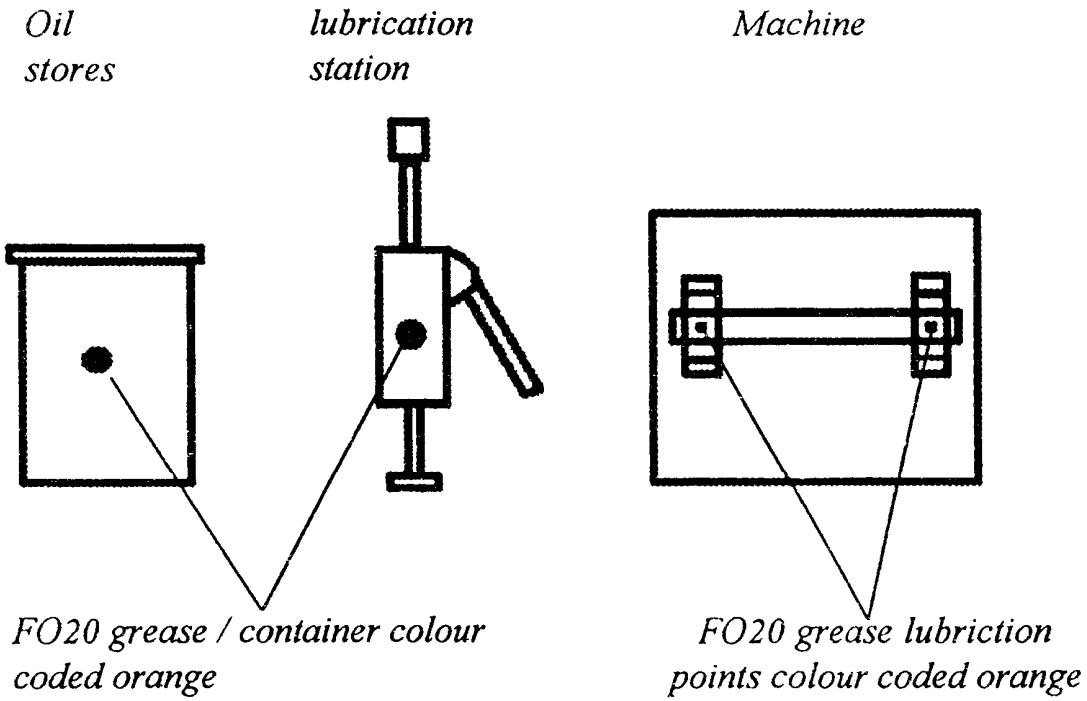
Is correct lubricant used?

All lubrication points should be marked clearly with the correct color code to be used.

All lubricant containers at the lubrication station should be color coded and filled with the correct lubricant to match that color code.

All lubricant containers stored in the oil store should be correctly color coded for the lubricant they contain.

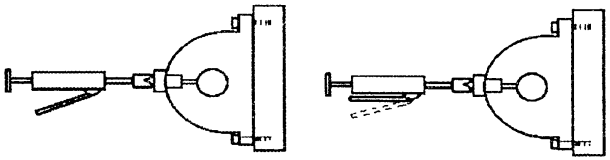
If this system is maintained correctly, then the correct lubricant will be used on the lubrication points of the machine.



* Using the wrong lubrication can have an adverse effect on the temperature, speed and loading of the moving part.

Amount of lubricant

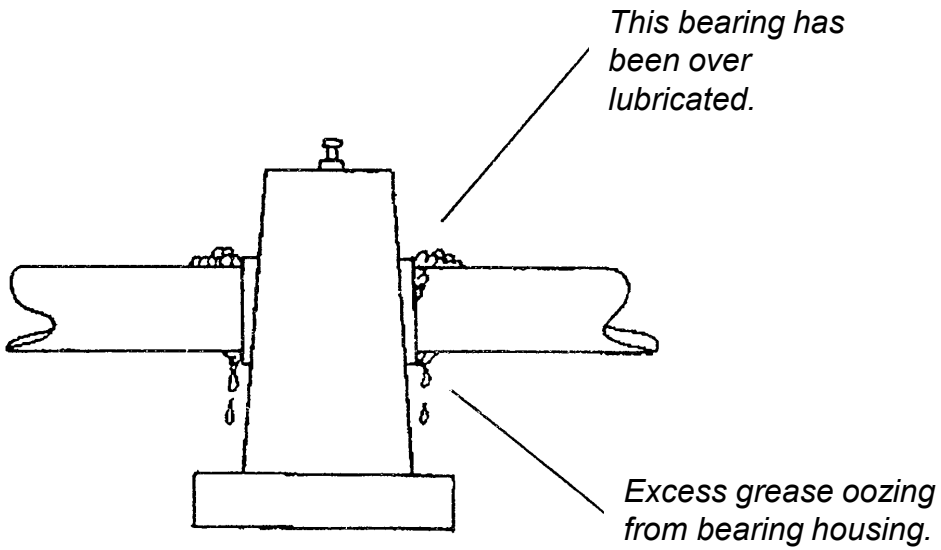
One shot of grease from a hand gun is normally sufficient to lubricate the smaller range of bearings. Hand grease oozing from the bearing housing, this will tell you that the lubrication of the bearing, is sufficient.

the excess grease at the bearing  gun must be cleaned off after lubrication is completed.

Excess grease left on component ere.

This contaminated grease could be drawn back into the moving part if left.

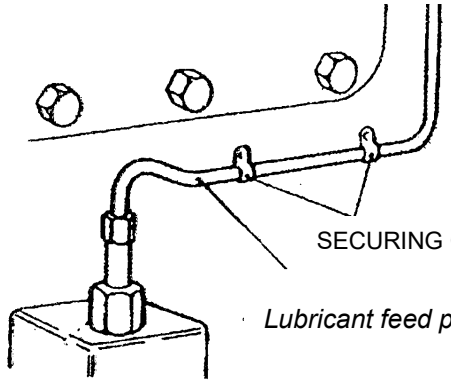
Regular greasing should be monitored to ensure that the moving is not being over or under lubricated. It can be regulated to the correct Quantity.



Reduce the amount on the lubrication schedule and check again next time.

Damage to pipes etc

Check for damaged feed pipes and coupling fittings on lubrication systems. Lubricant feed pipe lines and coupling fittings on lubrication systems should be in good condition, free of leaks and properly secured at all times.



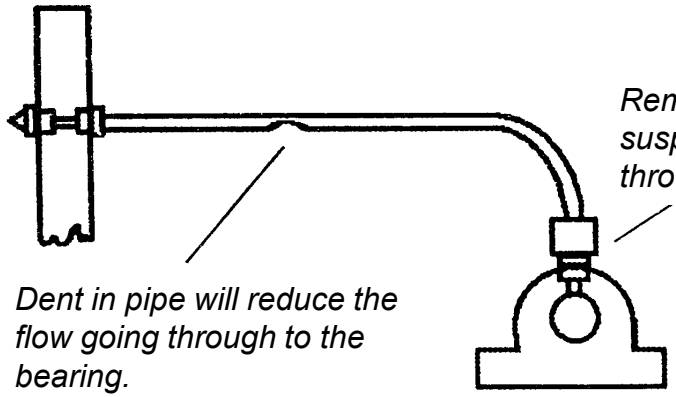
check visually for any obvious signs of damage, broken pipe securing clips and chafing of incorrectly supported pipes.

Check for any kinks, dents .e flow of lubricant to the moving part.

Damage coupling fittings o

If the feed pipe is suspecte :he moving part, should be removed and grease pumped through to check if full flov

Blocked lines should always be renewed immediately.

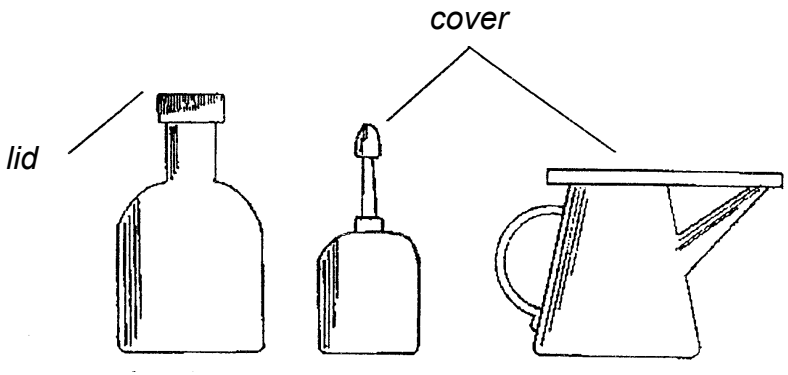


Remove here if blockage is suspect. Pump grease through the line to check flow

Dent in pipe will reduce the flow going through to the bearing.

Grease guns / bottles etc

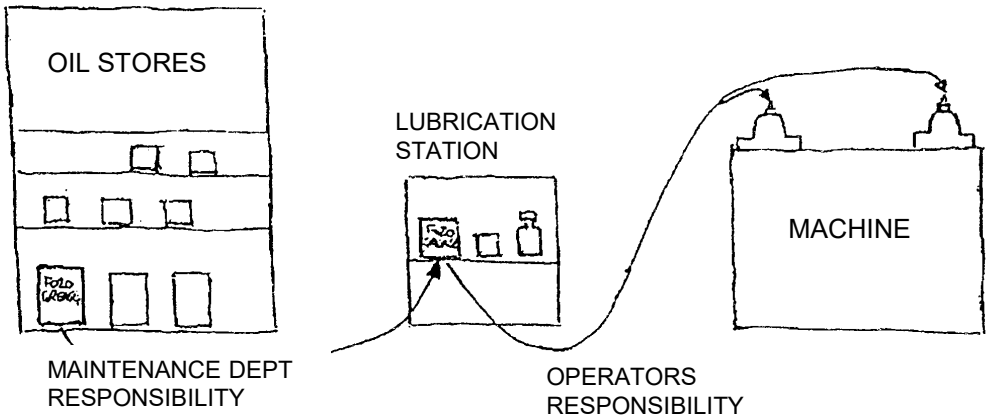
All hand grease guns, oil bottles and containers at the lubrication station need to be cleaned regularly to keep free of contamination. Also shelves are stored on. Ideally they should be stored in closed cupboards. Each of the lubricant containers should have a secure lid or cover fitted to ensure no contamination can enter the lubricant.



Always ensure that the containers ar whereby they are topped up after lubrication schedule has been comple

Amounts of lubricant used weekly or an adequate supply will always be available at the lubrication station.

It is the maintenance departments re fresh lubricant from the oil stores.

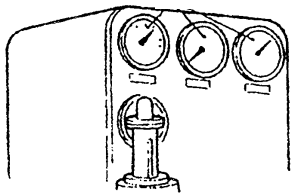


Monitoring the Lubrication system

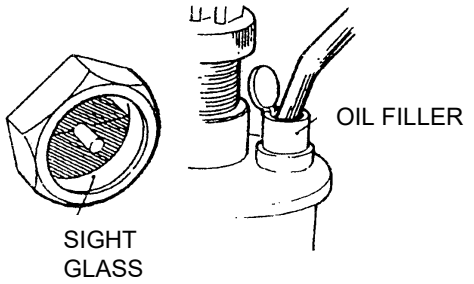
The system must be regularly checked and topped up to keep it operating to a high level performance and ensure moving parts are sufficiently lubricated at all times. Pressure gauges, oil sight levels, pressure switches, temperature gauges, filter systems and feed pipework should all be checked regularly to ensure lubrication system is operateing correctly.

Check oil pipe, unions and casing joints for obvious signs of leakage.

Check al oil pressure gauge readings

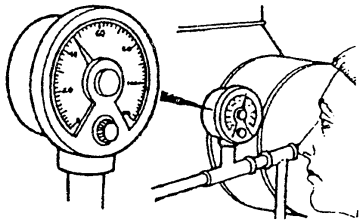


Check all oil bath, reservoir and sump levels (usually by dipstick or sight glass)



Direct reading dials

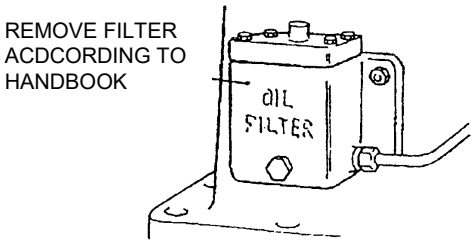
The temperature can be read direct from the scale



Remove dirty filter

Flush system with flushing oil if specified.

Fit new or clean filter as required.



Points to consider

When creating an inspection check for lubrication systems: –

a. Check grease nipples in the system for leakage through the no return valve of the nipple.

b. Distribution lines should be checked for kinds and chafing damage that could be causing blockage or leaks.

c. Moving parts that are lubricated by lubrication points should be visually checked periodically to see if they are being over–lubricated or under–lubricated. Readjust volume to meet the need.

d. Check sight glasses, pressure gauges, level indicators or any other indicators that are in the good working order and showing correct pressures and levels.

e. Do temperature checks on moving parts to establish they are working to a normal temperature, i.e. gearbox – touch by hand to see if it is hotter than normal. Has the temperature of oil increased in an Oil–Circulating System?

Monitor temperature.

f. On oil mist lubricator bottles and reservoirs, mark and monitor the level of the lubricant to determine the rate of usage.

g. On pumped oil circulation systems, regularly check the pressure the system is running at. A raised pressure can indicate a blocked filter. Temperature of the oil will increase if there is a blockage in the system when pump is running.

h. Check for water contamination in an oil system. Water will emulsify the oil – turning it a milky color. Oil needs changing if it is emulsified and source of water leakage rectified.

i. All oil bath, gearbox, reservoir and sump levels need checking periodically.

j. Check for oil leakage through seals and gaskets on gearboxes, reservoirs, pumps and any other components in the lubrication system.

Fact finding

You should now be able to do and answer at your machine each of the checks below. Where you have difficulty, please refer to the page and paragraph indicated to remind you.

		1 point	2 point	3 point	4 point	5 point	6 point
The audit (lubrication)	Do oiling places have a label correctly attached and are ideas incerperated to lubricate all places, without omission?						
	Is correct oil used?						
	Is oiling amount appropriate?						
	Check for oil deterioration.						
	Check for oil supply pipe dogging and damage.						
	Is oil to be supplied always available?						
	Are and oil lubricators managed for each of type?						
	Check for damage and attached dust and dirt on and nipples.						
	Are oil stations managed for each of type and are they always covered? Check for attached dust and dirt on them and their pollutions.						

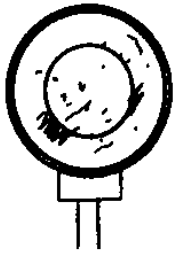
Point of cleaning

(Glasses of an oil leveler and instrument)

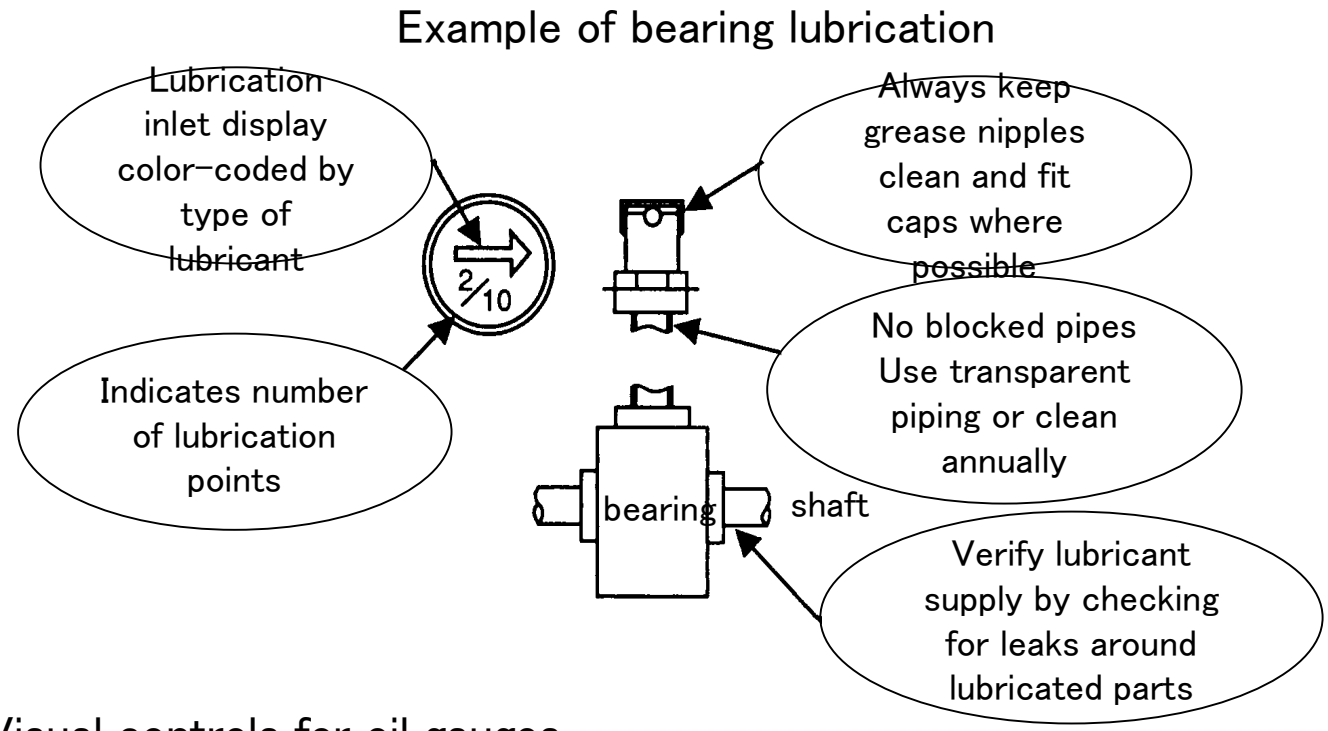
Cannot see the existence of oil and the degree of contamination

Oil leveler

Cannot see the scale



Instruments



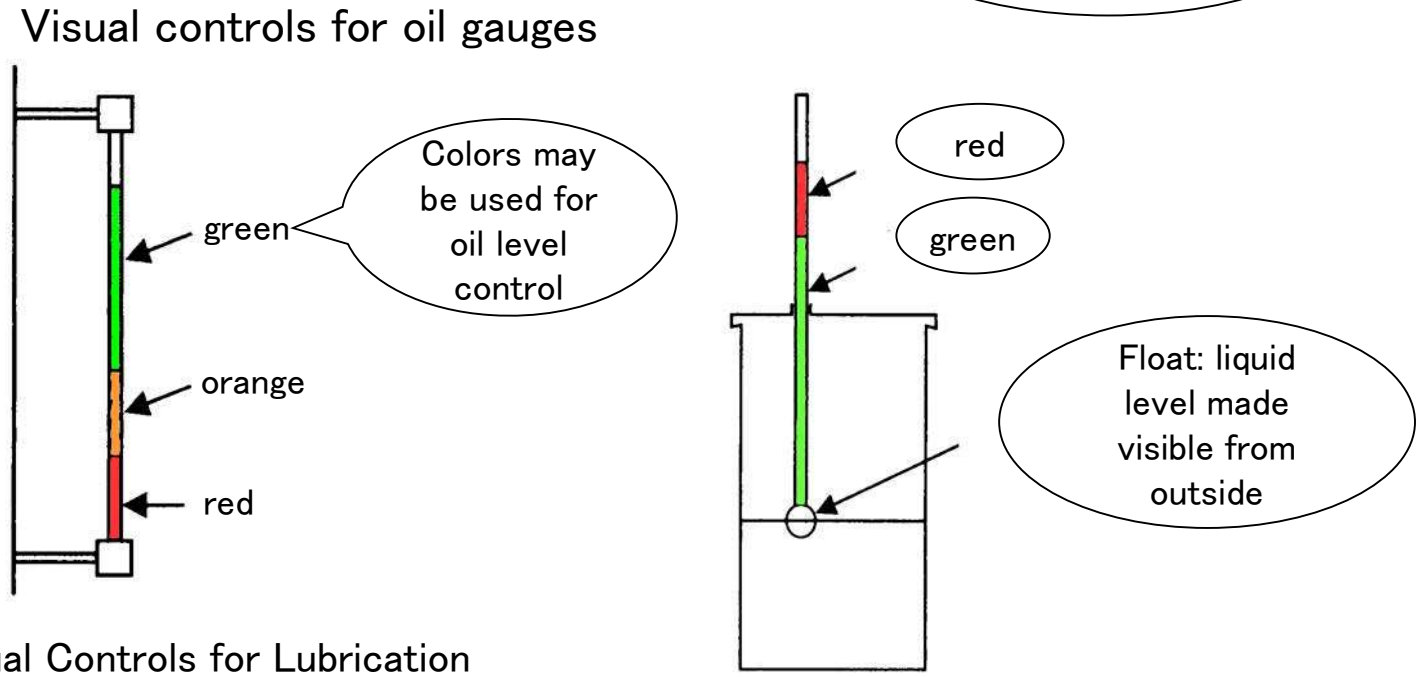
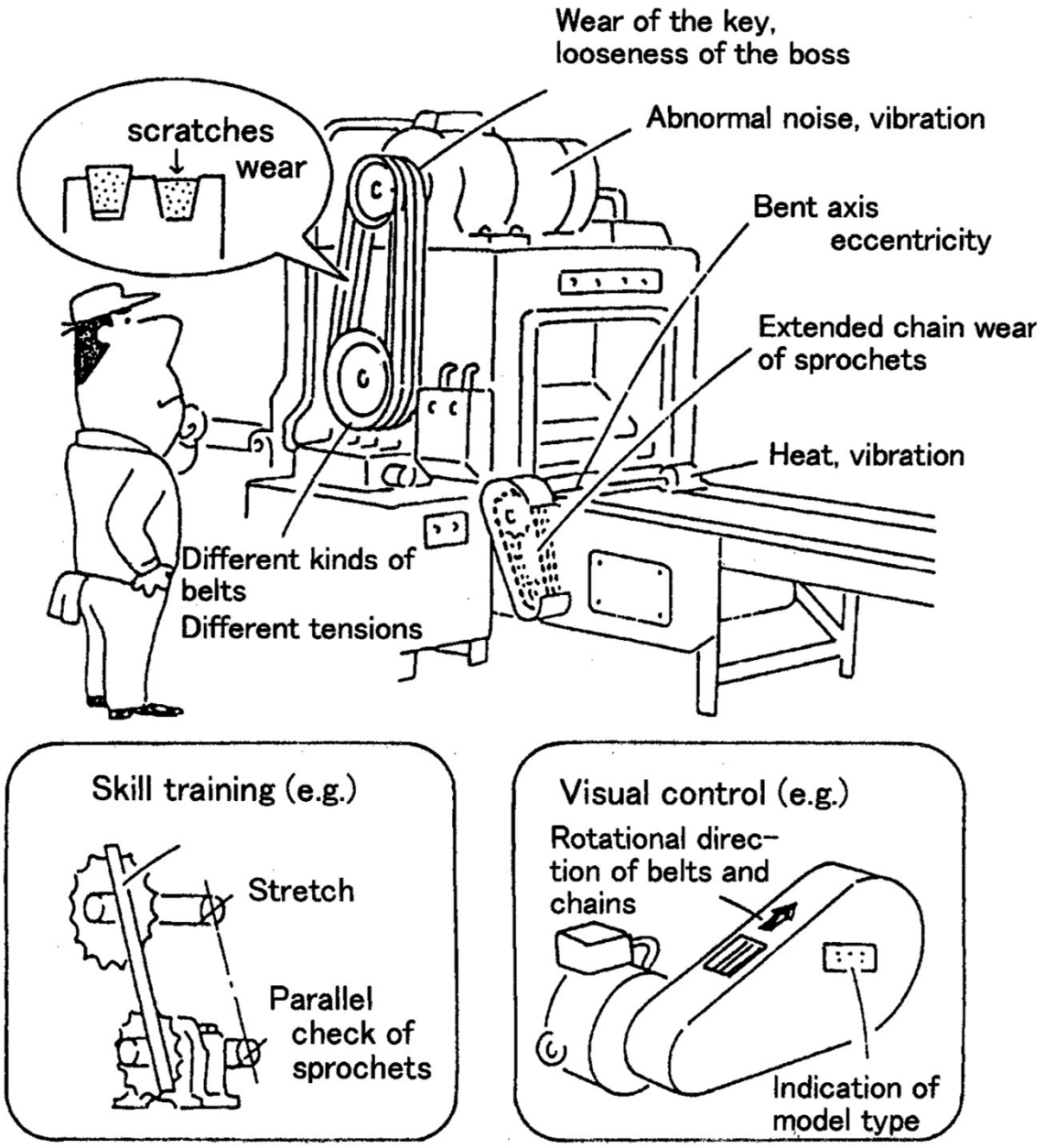


Figure. Visual Controls for Lubrication

Contents

Skills
Belt & chain drives
Definition of a drive unit
Description of a gearbox reduction unit
Gear train type gearbox
Worm wheel/worm shaft gearbox
What is a speed reducer?
Motor gearbox unit
Motor
Power transmission drives
Vee rope
Timing belts and pulleys
Alignment of power transmissions
Shaft alignment
Checking tensions
Securing components
Checking for wear and deterioration
Checking for wear, vibration and noise
Lubrication gearboxes and chain drives
Chain drive lubrication
Creating an inspection check

Drive System



Skills

1 – Extra skill and knowledge operator will require in order to carry out monitoring checks on drive systems.

a. Understand the function of a drive unit.

b. Beware of safe working practices when working in drive units.

c. Have knowledge of the components used for power transmission drives.

d. Have knowledge of the alignment and tensioning of power transmission drives.

e. Understand the faults that create overheating, vibration and excessive noise.

With this knowledge you will be able to understand better how your machine operates.

Belt & chain drives

Before working on the drive of any machine, isolate it from its power supply in a way that prevents the machine from being accidentally started.

safety

Before working on a drive:

A) Switch off machine.

B) Switch off the main supply to the machine and have the main fuses removed.

C) Put a warning notice on the main switch

D) Check to see if the machine has any other power supplies. If it has adopt the same procedure.

E) Check that the drive is stationary.

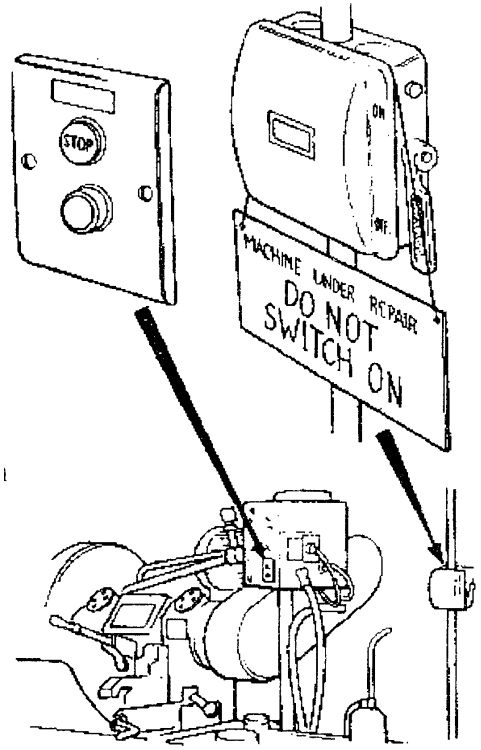
F) Remove the safety guards.

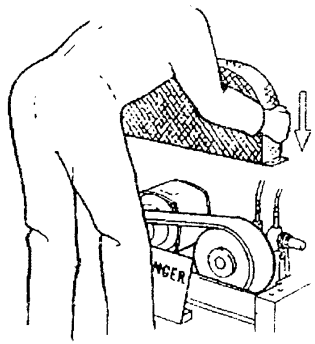
Before re-starting a drive:

A) Check that no tools have been left on or near the drive.

B) Replace the safety guards.

C) Restore the power supply and remove the warning notice.





Definition of a drive unit.

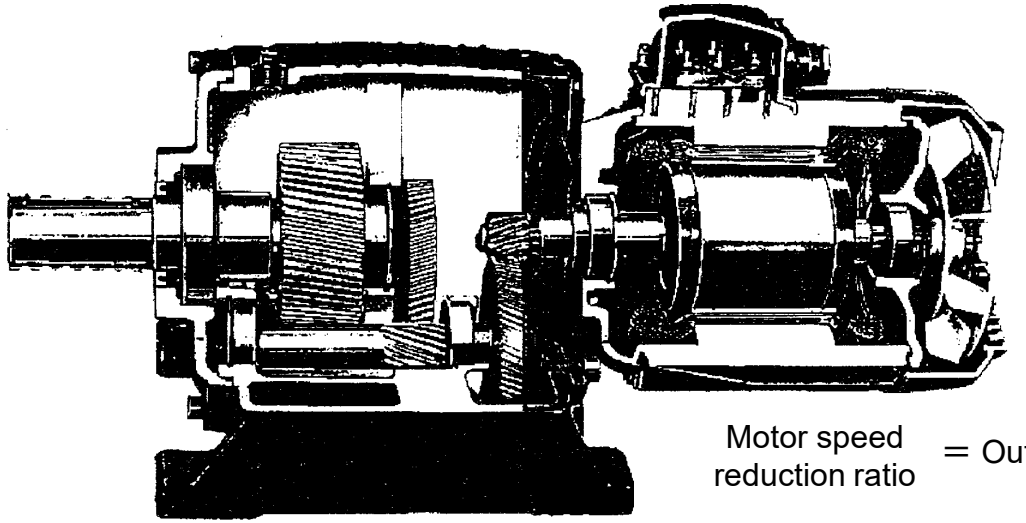
Drive units are the energy source for moving and turning parts of machinery. They transmit their power to driven parts either directly or by use of power transmission such as chains, vee ropes and timing belts. The heavier the load is, the bigger and more powerful the drive unit will be in order to cope with it.

Description of a gearbox reduction unit.

There are two different types of gearbox – a gear train type and a worm wheel/worm shaft type. Both types of gearbox have an input shaft, to which the electric motor is attached and an output shaft, to which the driven part is connected.

Gear train type gearbox.

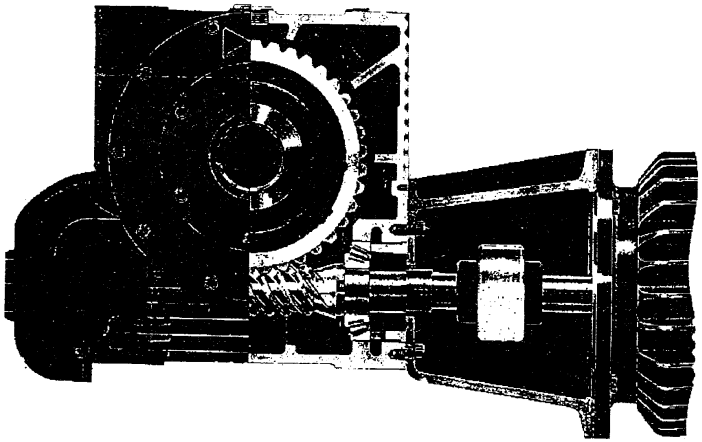
The gear train type gearbox has a series of different diameter gearwheels whose teeth are meshed together inside the box. When driven by the motor these gearwheels will reduce the motor output speed in stages until the speed of the gearbox output speed is the speed that is required for the application.



Worm wheel/worm shaft gearbox.

On a worm wheel/worm shaft gearbox, the only two components inside the gearbox are the worm wheel and worm shaft. The worm shaft is the gearbox input shaft, to which the motor is attached. The worm wheel is fitted to the gearbox output shaft, to which the driven part is connected. This gearbox is a one speed reduction type. The larger or smaller diameter the worm wheel will determine the ratio and speed of the gearbox output shaft.

What is a speed reducer?



A speed reducer is a mechanical unit whic at of the motor shaft.

A speed reducer, what for? To obtain

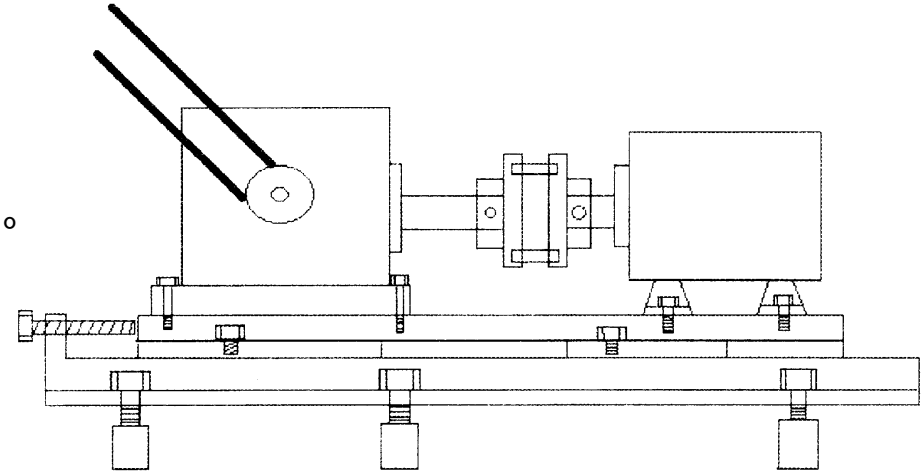
* A perfect constant output.
* An improved reliability (Unit protected b
* A larger reduction ratio range.
* A negligible maintenance (oil change eve
* A reduced size (compact design).
* A higher efficiency.

Motor gearbox unit

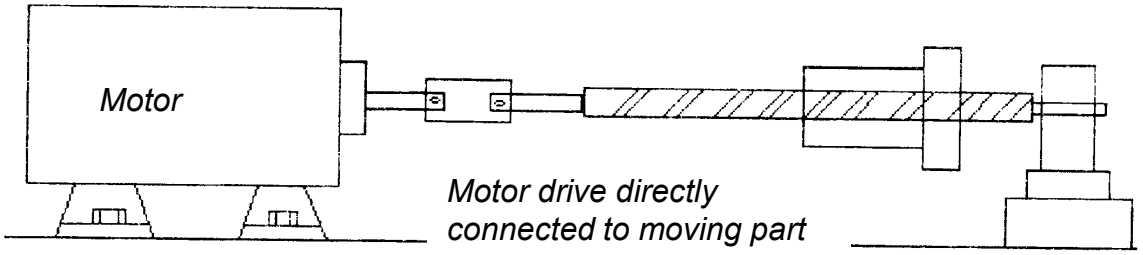
The motor and the gearbox are two separate units which are mounted on to a bedplate and are connected to one another by a drive coupling. It is essential that the alignment of the motor and gearbox are correct, otherwise rapid wear will occur. The gearbox output drive is transferred by power transmission to the driven part using chain, vee rope or timing belt (see sketch). The alignment and tension of the power transmission again are critical. Misalignment or slack tension will lead to rapid wear and slippage of drive.

Motor

An electric motor can be used o



n the case of light loads with fast speeds.



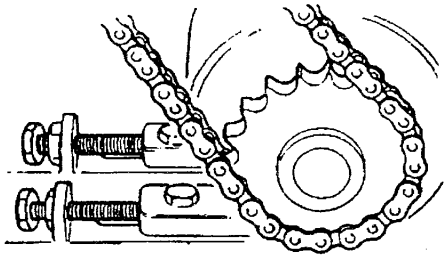
Power transmission drives

Power transmission drives are components such as chains, vee ropes and timing belts that transmit the power from a drive unit to the moving part it is driving.

Chain – Chain is used in conjunction with toothed sprocket wheels of the same pitch to transfer the drive to the driven part. It can be obtained in different pitches, i.e. ¼, 5/16", 3/8", ½", 5/8", …". It can also be obtained in: – simple chain (single); duplex chain (double) and triplex chain (treble).

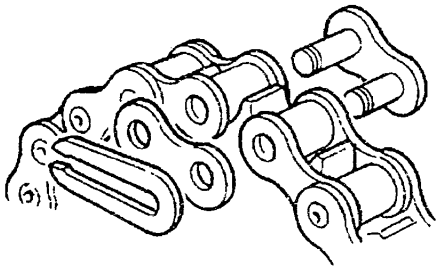
The ends of the chain are connected together by a split link of the same pitch.

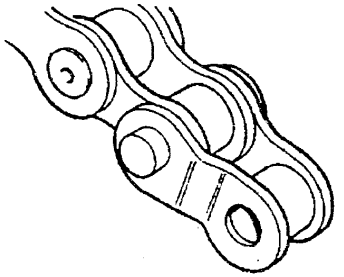
The length of the chain can be altered by half a pitch by use of a crank link of the same pitch.



ADJUSTING
SCREWS

Adjusting chain tension:
a. Slacken off the adjustment clamping bolts.
b. Move the pulley with the adjusting screws to alter the tension. Note: The adjusting screws must be turned equally to keep the pulleys correctly aligned.
c. Tighten the clamping bolts.
d. Check the tension. Note: Chains should be adjusted at the tightest position as they stretch unevenly.

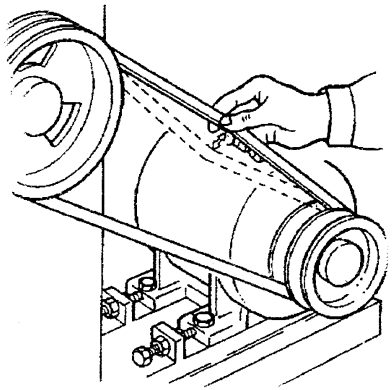




Vee rope

Vee rope is used in conjunction with vee grooved pulleys to transfer the drive to a driven part. The vee rope is available in a large variety of sections and lengths. When new they are all marked with their section and length on them. The section of a vee rope can vary from a small section to a large section.

The main ones on stock are: – M section, A section, B section and SPC to SPZ sections. The vee rope is a good fit in the tapered groove of a vee pully of the same section. The more tension that is placed on the vee rope the more it will grip into the taper of the groove. Unlike chain, the vee rope does not require lubrication. A vee rope drive can slip on the pulleys under excess load, unlike chain that is held onto the pitched teeth of sprockets and does not slip.



Tensioning belts:

Belts must be tensioned correctly to transfer the drive and prevent unnecessary wear. They stretch in use, their tension must be regularly checked and adjusted.

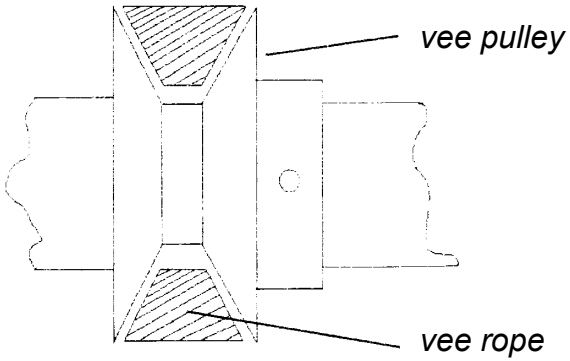
Measuring deflection in a slack belt.

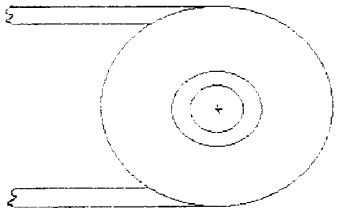
a. Check the specified deflection in the manufacturers instructions.

b. Find the middle of the longest span of belt between pulleys.

c. Push this mid-point inwards then pull it out and note the total deflection which should indicate the tension.

d. Adjust the tension as necessary.





Timing belts and pulleys

Timing belt – A timing belt has pitched teeth on the inside of the belt and is used in conjunction with timing pulleys of the same stepped pitch to transfer the drive to a driven part. The pitched teeth of the timing belt fit snugly into the pitched teeth of the timing pulley and prevent slippage of drive.

Power transmission – Timing Belts and Pulleys –

Bells of standard lengths are readily available in the following pitches and widthsex

XL extra light	6.5mm 9.5mm
L light	13mm, 19mm
	25mm
H heavy	19mm, 25mm
	38mm, 51mm
	76mm
XH extra heavy	51mm, 76mm
	102mm

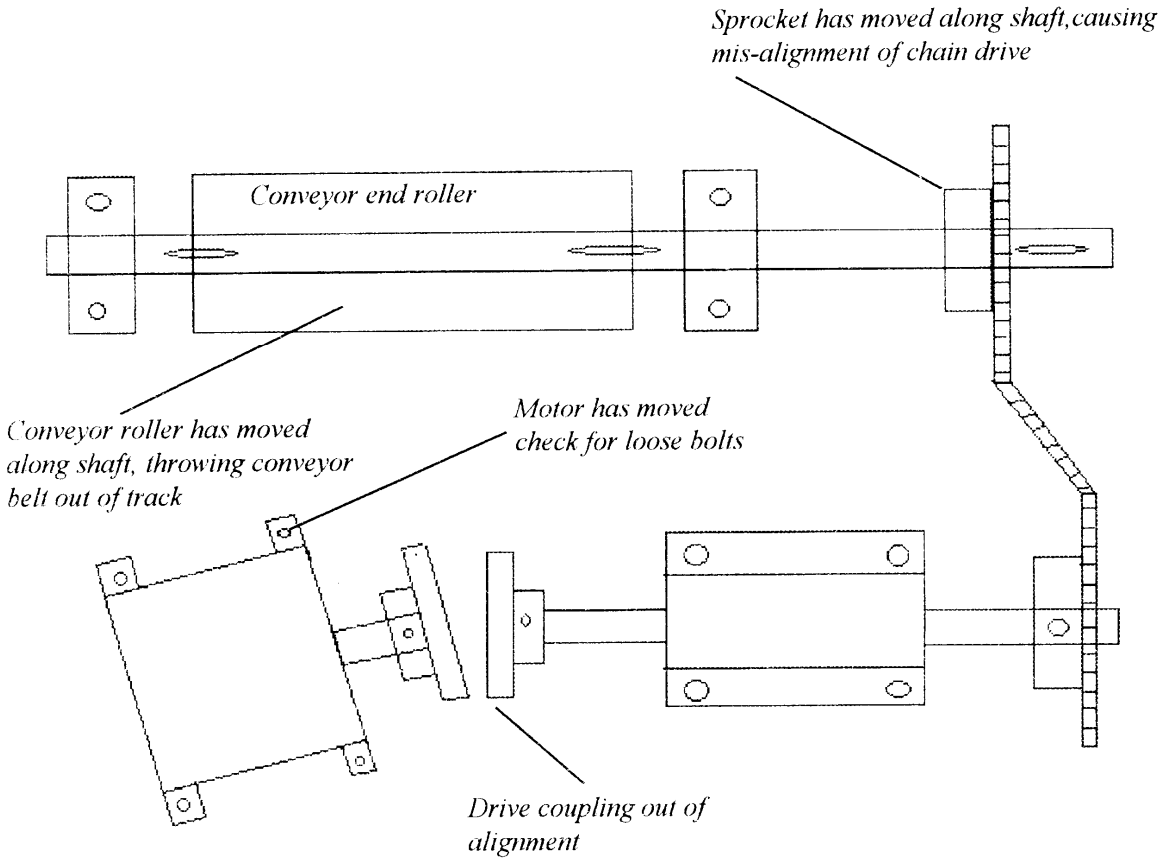
Non–standard belt widths are available but subject to minimum order quantities.

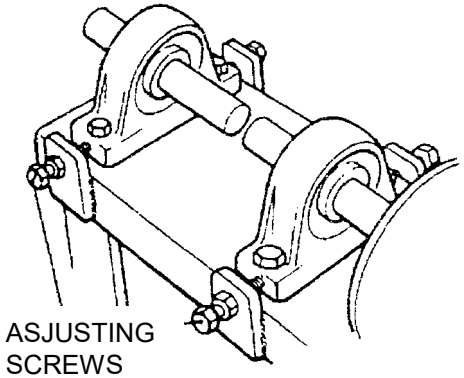
The following nomenclature is used to identify fenner timing belts. 1. Length – The first three figures of the belt designation are a measure of the pitch length. 2. Pitch – The letters indicate tooth pitch as follows: XL Extra light 5.08mm, L Light 9.53mm, H Heavy, 12.70mm, XH Extra heavy 22.23mm. #. Width – The figures following the letters in the belt designation indicates the width of the belt. Special construction timing belts. Belts utilizing stainless steel cords having anti–static special thickness or finish requirements and for use outside the normal –30℃ to + 85℃ temperature limits can be supplied. However, they are usually made to order and subject to minimum order quantities and surcharges. When considering the use of non–standard belts consult Fenner. Standard pulleys – Our comprehensive range of pulleys are made in L, H and XH pitches from high grade cast iron except some of the smaller sizes which are made from mild steel. The blanks are accurately machined and the teeth generated to tolerances which ensure correct meshing with the belt. In every timing belt drive at least one pulley must be flanged and for reasons of economy it is ususal for this to be the small pulley. The flanges are flared to ensure correct entry of the belt. Both pulleys should be flanged

if the drive center distance is more than eight times the diameter for the small pulley and on all drives with vertical shafts. Standard pulleys having less than 60 teeth in L and H pitches and 48 teeth in XH pitch are flanged. The following nomenclature is used to identify Fenner timing pulleys. 1. Number of teeth – The first two or three figures of the pulley designation indicate the number of teeth, e.g. 22H150 indicates 22 teeth. 2. Pulley pitch – Letters indicate the pitch as follows: L Light 9.53mm, H Heavy 12.70mm, XH Extra heavy 22.23mm. 3. Pulley width – The figures following the letters in the pulley designation are an indication of belt width. Special pulleys. Pulleys of non-standard width and shape together with special flanging arrangements can be supplied to order. Teeth can also be cut in customer own blanks. Consult Fenner when considering non-standard pulleys. The timing belt needs to be always tensioned correctly to keep the pitched teeth enmeshed into the teeth of the timing pulleys at all times. A slack timing belt will jump the teeth and stagger the drive.

Alignment of power transmissions

The correct alignment of all components on drive unit is critical for the unit to operate at its optimum level of performance. Misalignment causes rapid wear and deterioration of components.





Horizontal alignment:

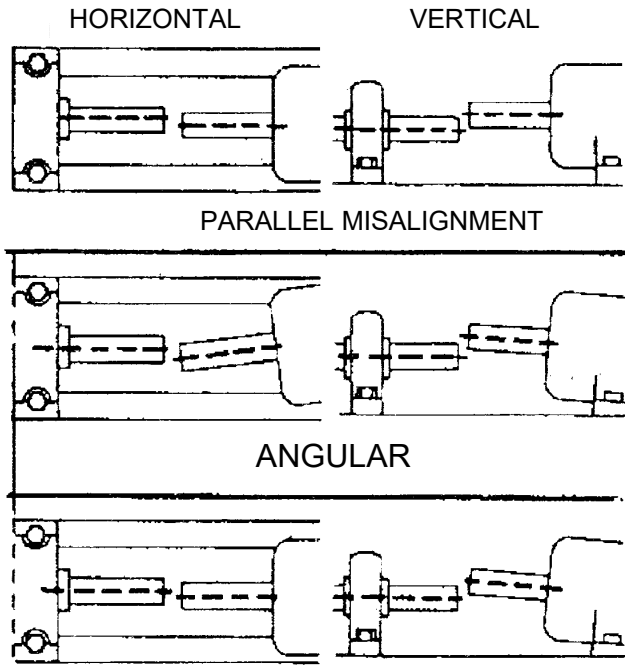
a. Place the straight edge along the side of the shafts.

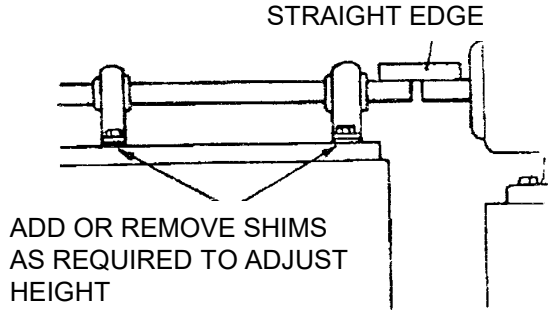
b. Correct any misalignment by loosening off the plummer block mounting bolts and moving the blocks sideways are required. Tighten the mounting bolts and re-check alignment.

c. Repeat procedure until correct alignment is obtained.

Shaft alignment:

Shafts must be accurately aligned when fitted, as any misalignment will damage or shorten the life of both the bearings and the couplings. Machines bed down when they are used, so the shaft alignment must be checked regularly and corrected if necessary.





Checking alignment

There are several methods of checking alignment. It may be done using a straight edge, a dial test indicator or a vernier height gauge.

Before beginning an alignment check:

a. the mounting surfaces must be clean and flat.

b. The mounting bolts must be tight. Alignment must be checked in both horizontal and vertical planes.

1. Using a straight edge.

The use of a straight edge will provide a sufficiently accurate alignment check when a flexible coupling is to be used.

Vertical alignment.

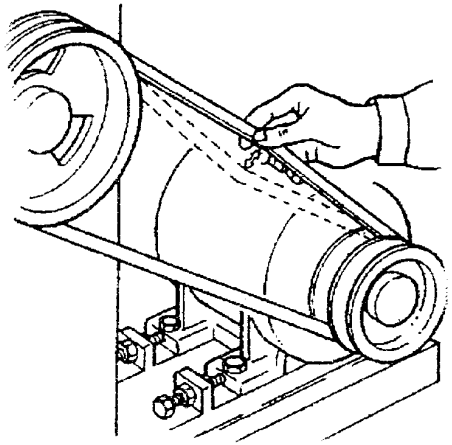
a. Place the straight edge along the top of the two shafts.

b. Correct any misalignment by adding or removing shims under the appropriate plummer blocks.

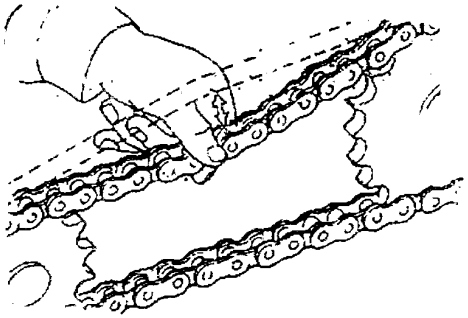
Ensure that burns are removed from shims before placing them in position and that the mounting bolts are tightened down before each check. An inspection lamp should be placed behind the straight edge to reveal whether shafts are aligned vertically.

Checking tensions

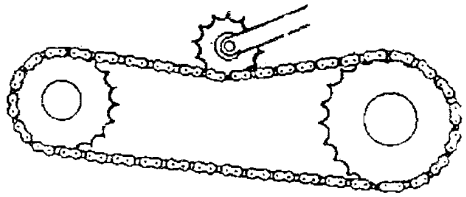
Slack vee belts and chains on power transmission drives will allow the drive to stagger or jump and reduce the specified speed of the moving part. This slippage of the power transmission drive leads to wear and damage to vee belts, vee pulleys, chains and chain sprockets.



Tensioning belts:
Belts must be tensioned correctly to transfer the drive and prevent unnecessary wear. As they stretch in use their tension must be regularly checked and adjusted. Measuring deflection in a slack belt:
a. Check the specified deflection in the manufacturers instructions.
b. Find the middle of the longest span of belt between pulleys.
c. Push this midpoint inwards, then pull it out and note the total deflection which should indicate the tension.
d. Adjust the tension as necessary.



Chain tension:
Chains wear and stretch during use, therefore their tension must be checked and adjusted regularly.
Measuring deflection in a chain:
a. Find out what the correct amount of deflection is.
b. Find the middle of the longest span of chain between the sprockets.
c. Push the mid-point in, then pull it out and note the total deflection.
d. Compare with the correct deflection.



Jockey sprocket:
A spring loaded jockey sprocket can be used to tension a chain which transmits the drive between sprockets with fixed centers.

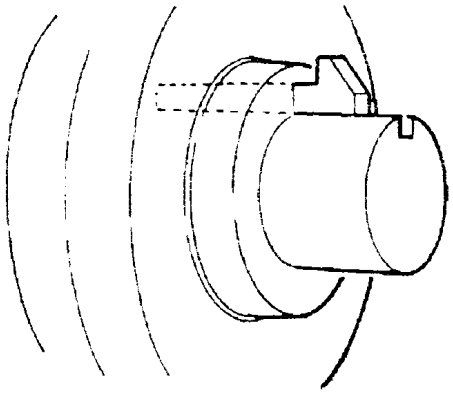
Securing components

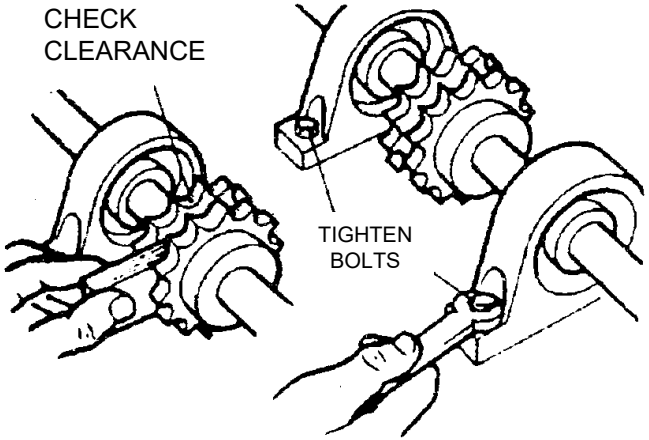
Driving members:

Drive wheels such as pulleys and chain wheels need to be located so that the driving power can be transmitted.

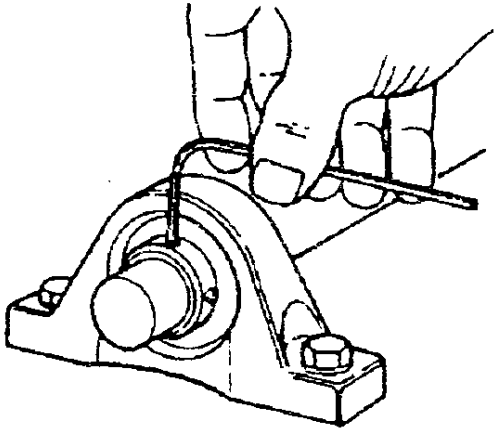
Methods of securing.

Tapered key: These can be used to clamp a driving wheel in position along the shaft. They are normally used on larger shafts.



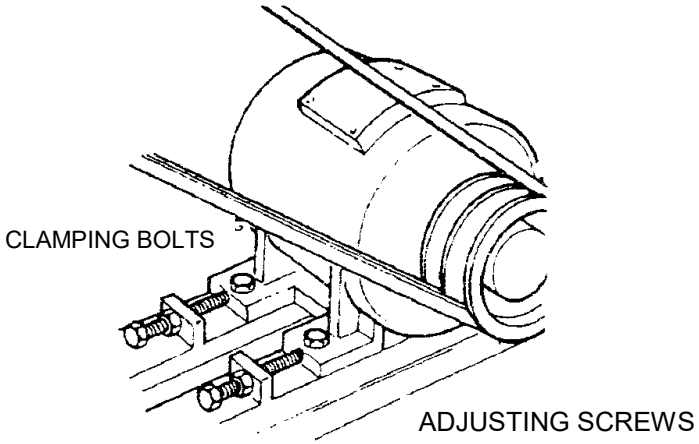


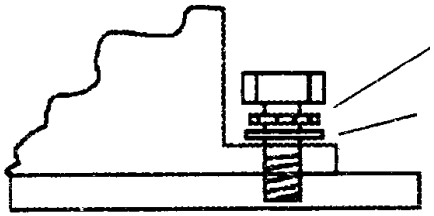
Check the clearance between the ends of the shafts or the parts of the coupling. Tighten the bolts in the shaft mounting.

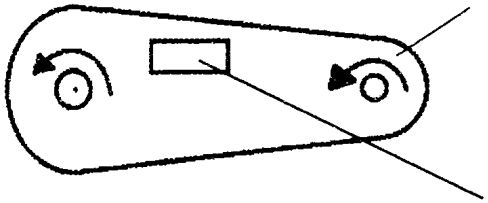


Tighten the lock screws in the plummer blocks equally to clamp the shaft. Align the shaft (see next section). Tighten mounting bolts.

Ensure all holding down bolts for gearboxes, motors and bearing housings are tightly secured and are all fitted with locking devices.





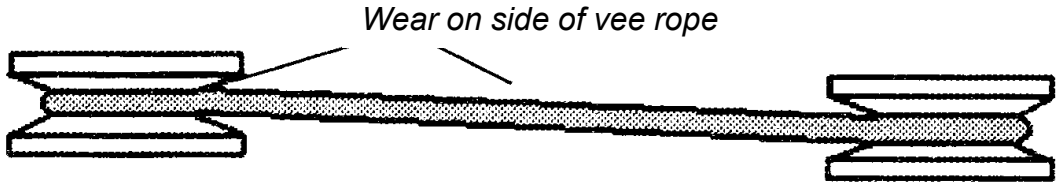


Ensure shafts are marked with rotating direction.

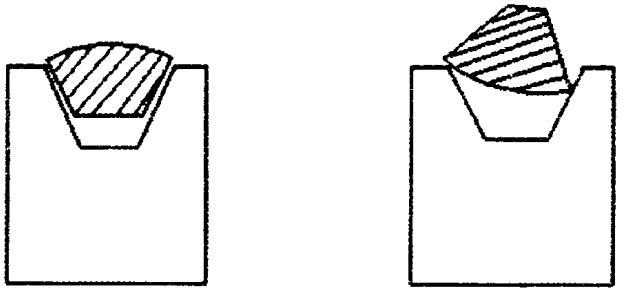
Ensure belt size information is displayed on drive guard.

Checking for wear and deterioration

Vee belts and chains on power transmission drives require regular inspection for wear, damage and alignment. The vee belts and chains can become worn and damaged through misalignment, slackness and excessive loading.



Slack and misaligned vee belts can turn over in pulley taper grooves causing severe slippage of drive: -

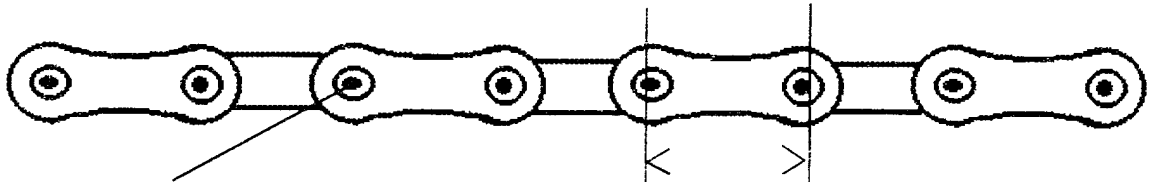


Correct

Wrong

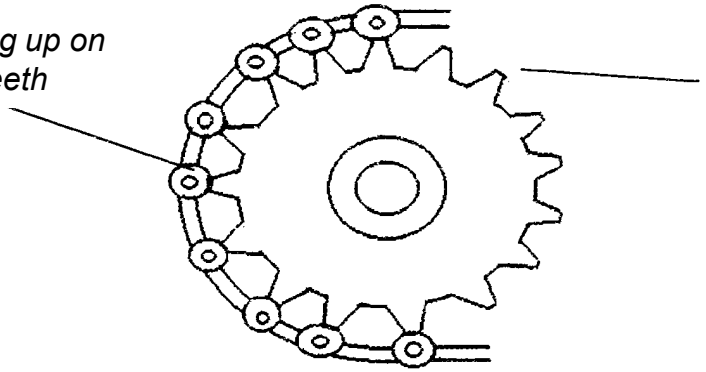
Vee belt has turned over causing damage to belt section.

Worn drive chains become elongated and the pitch length increases. This causes the chain to jump the teeth of the sprocket, slowing down and staggering the drive speed.



Wear on pins and bushes

Pitch length increased



Chain riding up on sprocket teeth

When this happens, the tip of the teeth rapidly wear

Checking for wear, vibration and noise

Moving parts such as gearboxes, motors, bearings etc. Create and maintain a certain amount of heat while running. This is known as the working temperature. If felt by hand, this is normally a pleasant warm feeling.

If this temperature become uncomfortably hot when felt by hand, it is a sign that something is wrong and requires investigation: -

a. Has the temperature increases dramatically?

b. Is the moving part getting sufficient lubrication?

c. Is the moving part aligned correctly?

d. Are the holding down bolts of the moving parts secure?

e. Is the power transmission drive properly tensioned? Overtight belts and chains place excessive load on bearings.

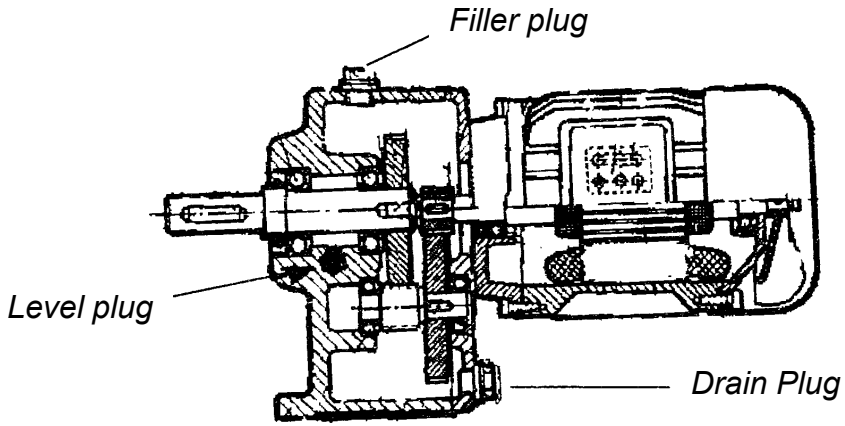
f. Is there excessive noise from the moving part indicating a collapsed bearing?

These are checks that need to be made at regular intervals on drive units.

Temperature indicating labels can be placed on motors and gearboxes to visually indicate the temperature. It gives present temperatures and past temperatures.

These indicating labels are still to be evaluated.

Lubricating gearboxes and chain drives



The oil inside the gearbox is filled to the level plug. This oil level is critical for the gearbox to operate to its optimum level of performance.

Too high an oil level will increase the temperature the gearbox will run at.

Too low an oil level will starve some of the components of lubrication. The splash lubrication won't be as efficient.

The oil level can be checked by removing the level plug – if too much oil is in the gearbox, allow it to run out of the level plug hole until it stops. The oil level in the gearbox will then have the correct level of oil.

If no oil comes out of the level plug hole, add more oil through the filler plug until it starts oozing out, the gearbox will then have the correct level of oil.

a. Check temperature of gearbox. If it is higher than normal check the oil level is correct.

b. Check the alignment of the gearbox is correct.

c. Check noise level gearbox is running at excessive rumbling can indicate a worn bearing or worn gear teeth.

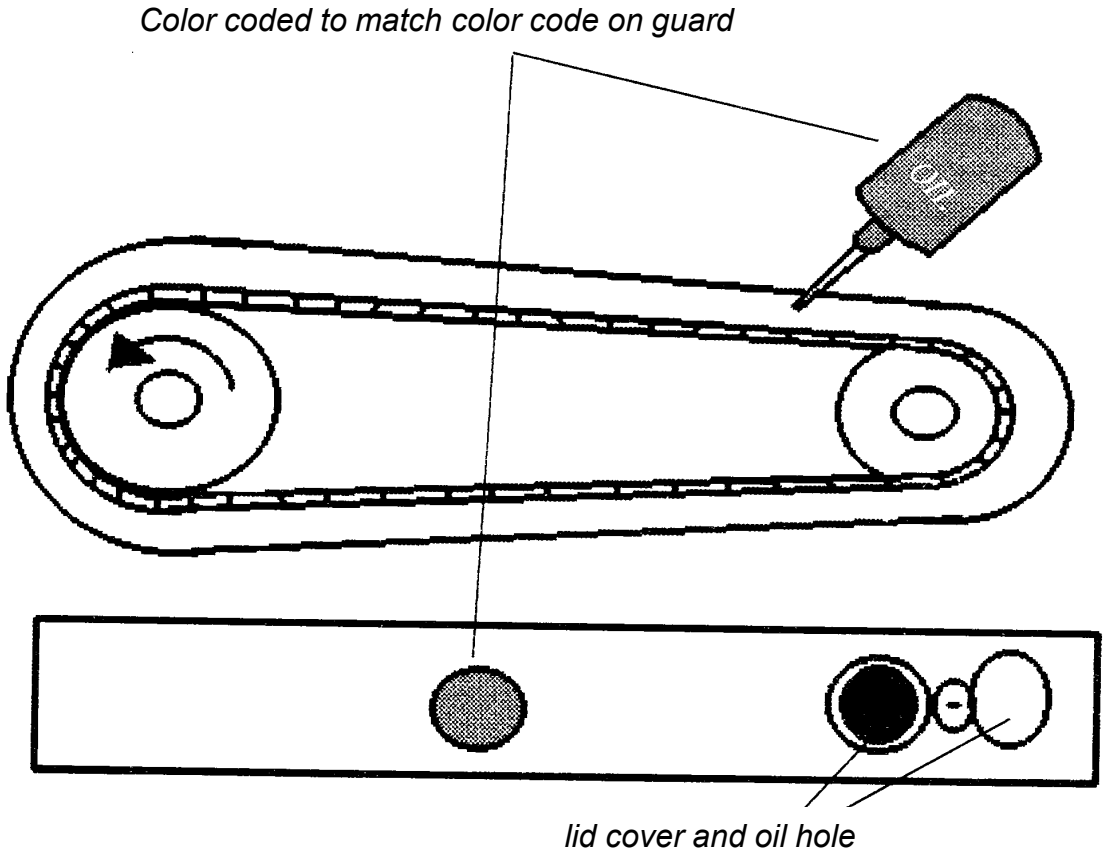
d. Check vibration level. If excessive check for loose holding down bolts and alignment.

e. If fault continues report to maintenance department.

Chain drive lubrication

Drive chains require regular lubrication. Otherwise the pins and bushes on the chain will wear and seize up. The chain will become elongated and sloppy and eventually jump over the sprocket wheel teeth.

Always ensure the lubrication has got onto the teeth of the sprockets. This will save the teeth from undue wear.



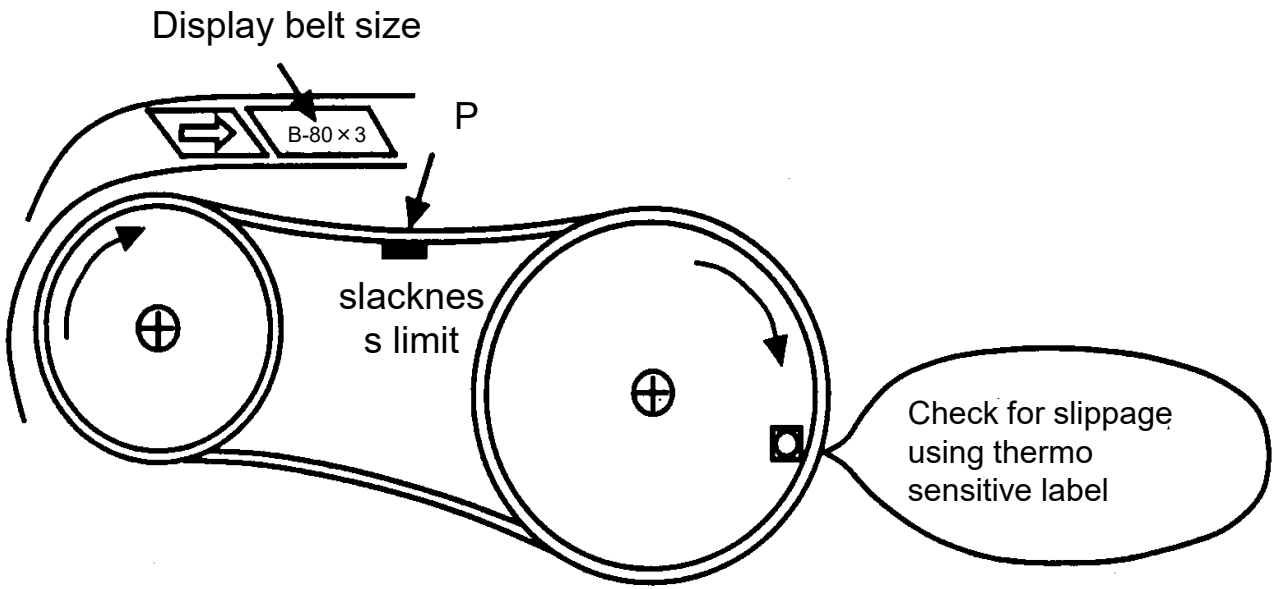
The drive chain can be lubricated in various different ways. The above method by oil bottle can result in excess oil lying at the bottom of the guard. It could also be lubricated with a drip feeder, spray can or brush feed directly onto chain.

<u>These methods would need to be tested and evaluated.</u>

Creating an inspection check

1. All drive units on the machine need to be located and marked on drawing or sketch.
2. The function of each drive unit should be identified – what is it driving?
3. The alignment of every drive unit is critical. Misalignment leads to rapid wear and slippage of drive.
4. The tensioning of power transmission is critical i.e. chains, vee ropes, timing belts. Over tensioning results in excess load and wear. Under tensioning creates slippage and staggering of drive.
5. A drive unit runs at a working temperature. If this temperature rises it is a sign that something is wrong. Is one of the components beginning to wear or break up? Needs to be investigated.
6. When running a drive unit will create a certain noise level. Is there any increase in this noise level? If there is it will indicate that something is wearing or misaligned.
7. A regular visual check needs to be carried out on drive units for wear and damage. Also tension and alignment.
8. The guarding of drive units is of paramount importance. Ensure these guards are correctly fitted and secure. Also that they are free from damage.

Slackness limit



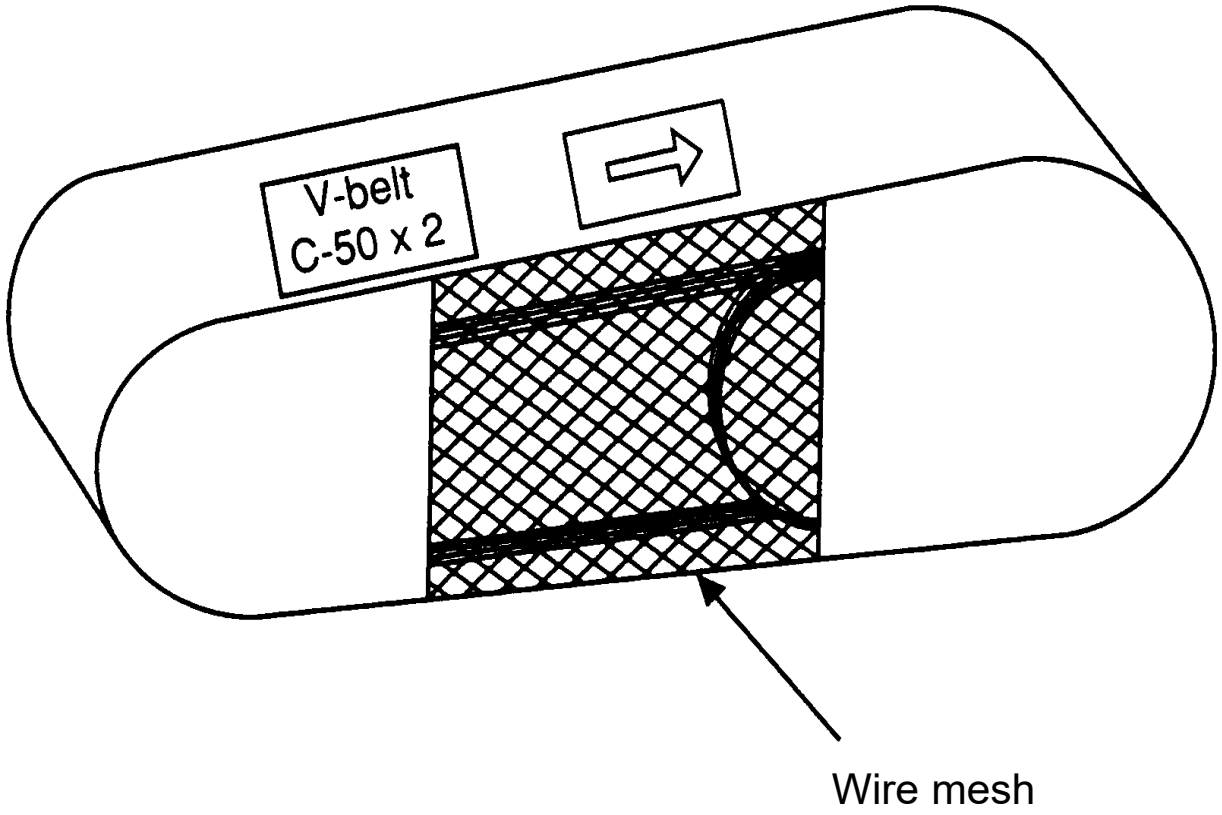
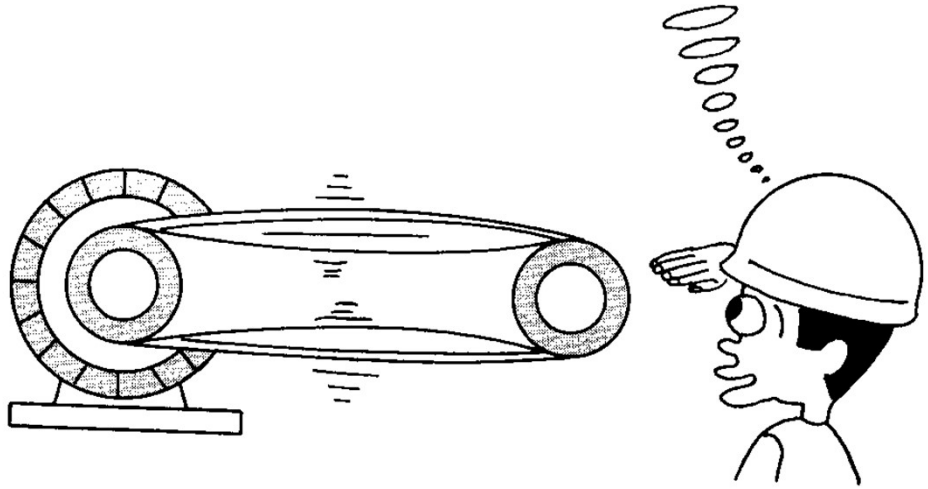


Figure. Indicate Belt Size on Safety Cover

Do not allow V belts to vibrate laterally !

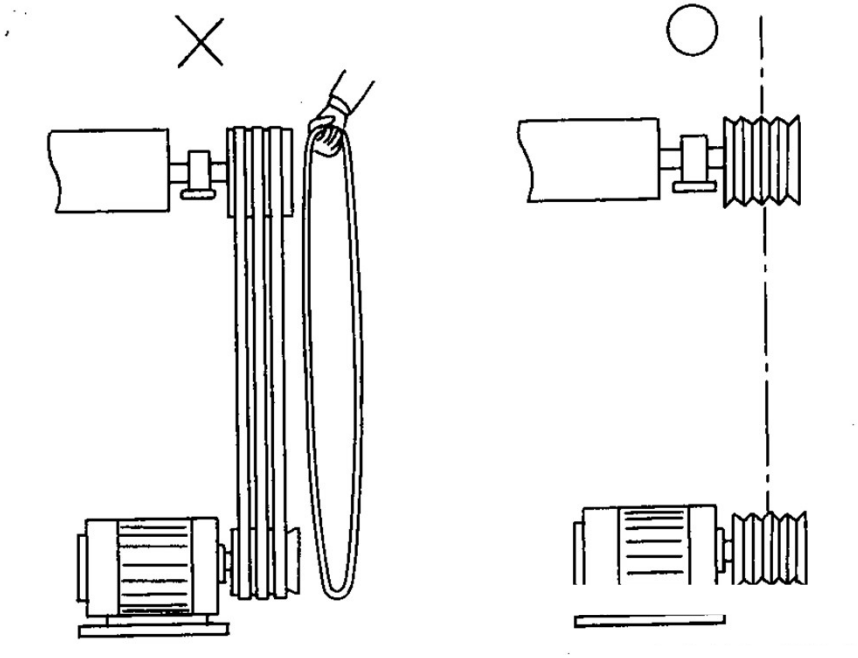
When bearings are hot, belt tension is too high. When the pulleys are hot, belt tension is too low. Slips take place.



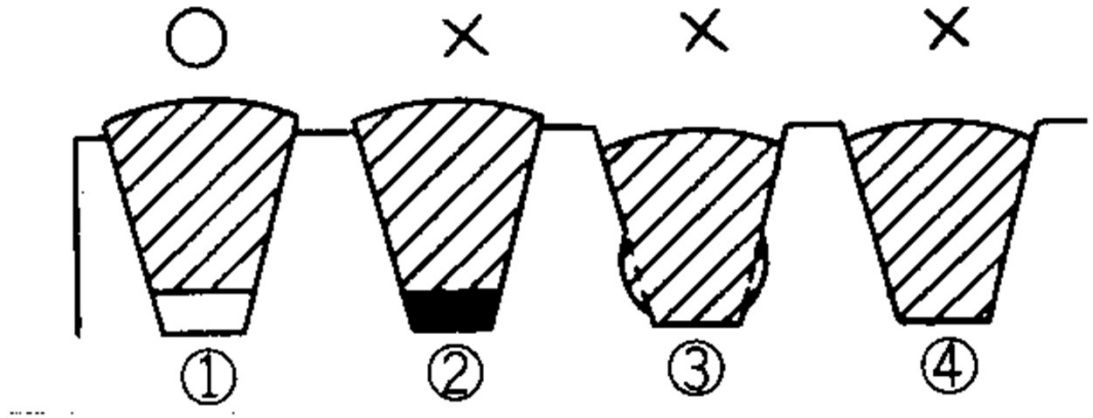
The causes of lateral vibration :

- Eccentricity
- Wear
- Looseness

Do not change one belt only!
Replace all the belts at the same time!



Do not use V belts in the situations of ②,③ and ④ in the figure!

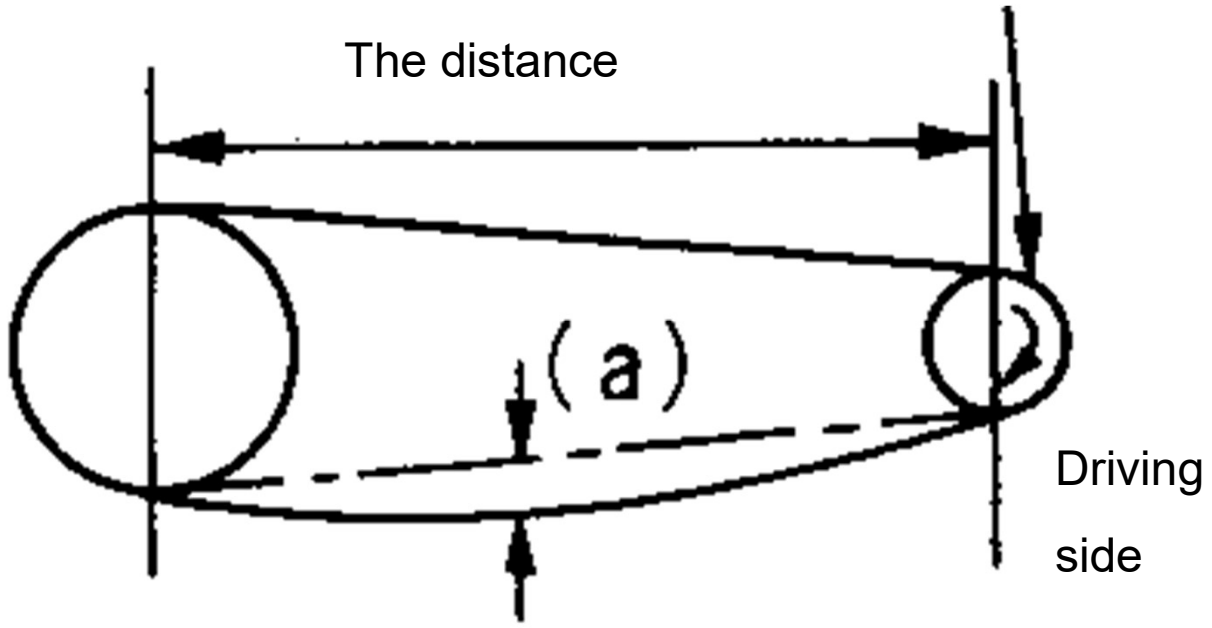


Foreign body

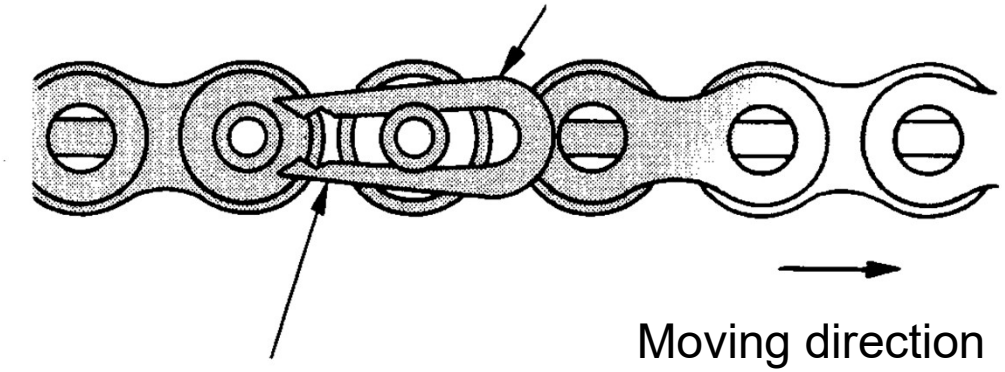
Worn pulley

Worn belt

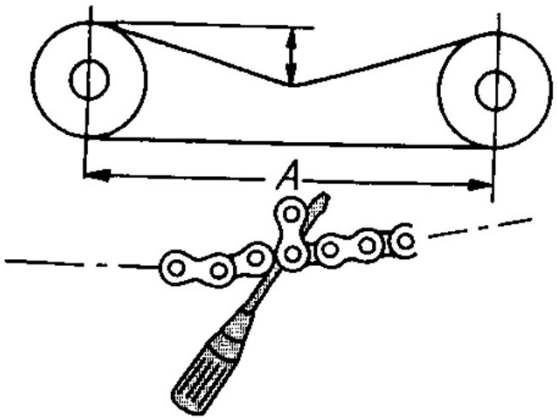
Do not allow a chain to be slacking more than 2% of the distance between the two axes !

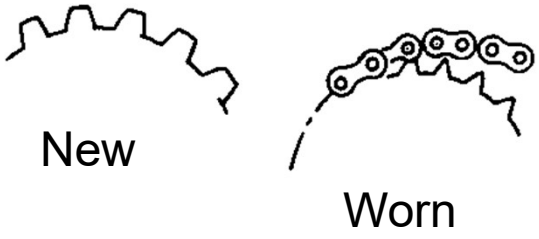


Do not direct stopping clips of a chain towards the rotating direction !

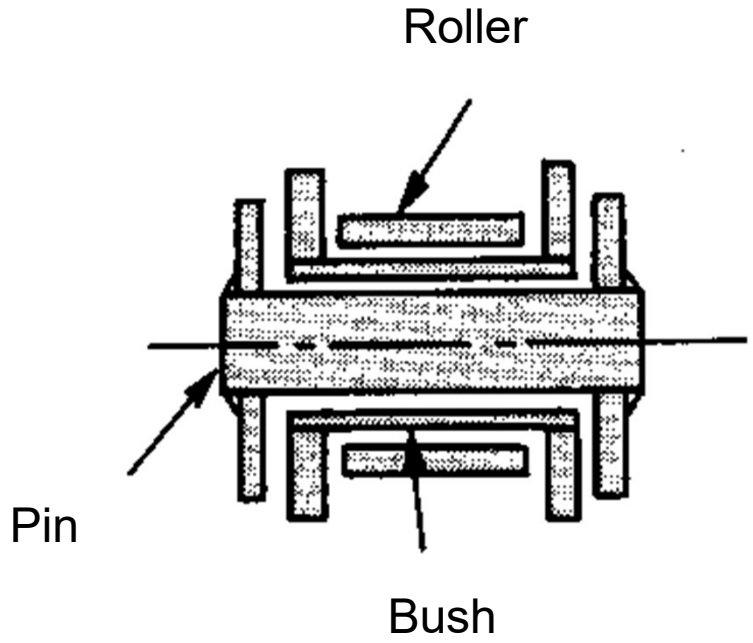


Do not allow a chain to jump over a tooth of a sprocket!

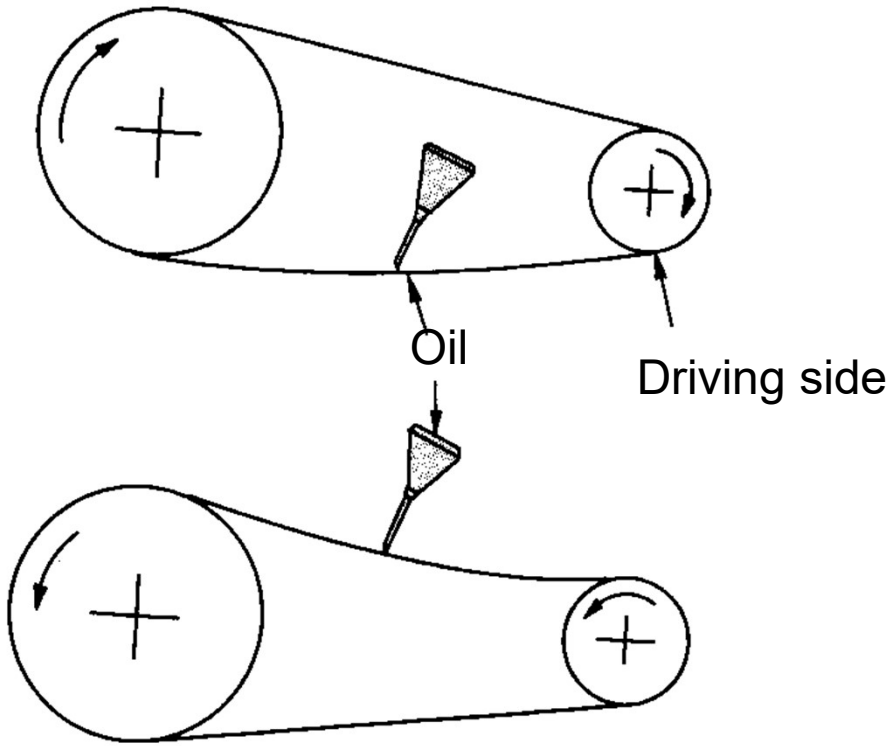




Do not grease chains, use oil!



Charge oil to a chain at the loosened side.



Pneumatics

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Skill level
Compressed air for a pneumatic system
A simple pneumatic system
Filter set for a pneumatic system
A filter set
Air gauge
An oil mist lubricator
Drain valve
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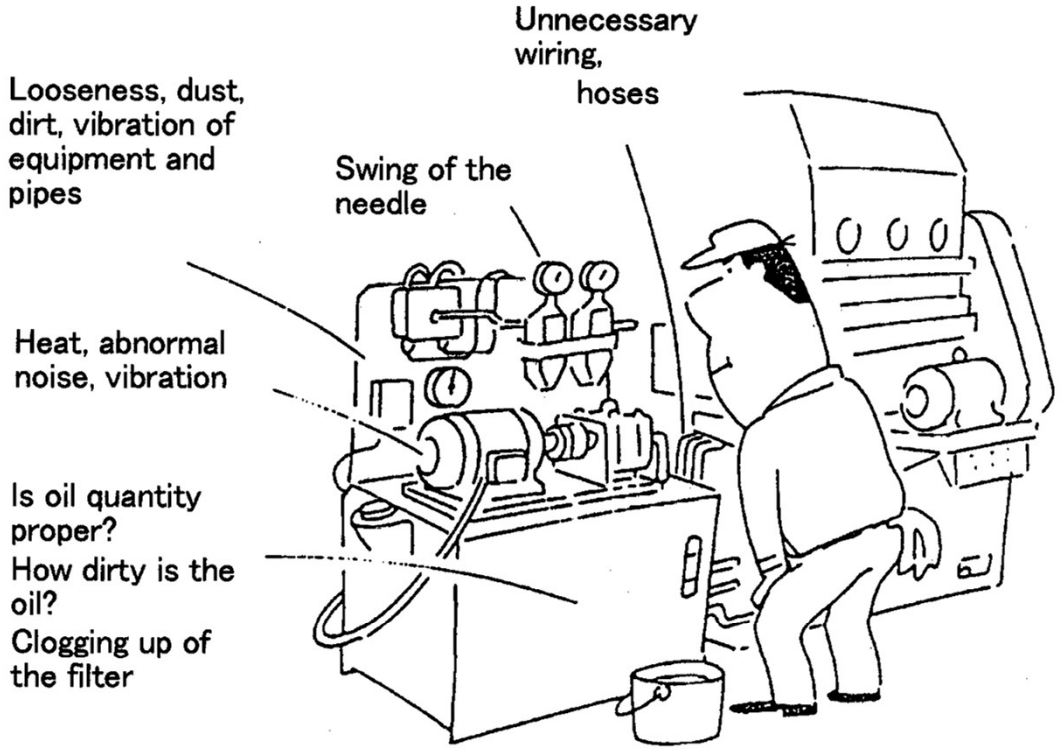
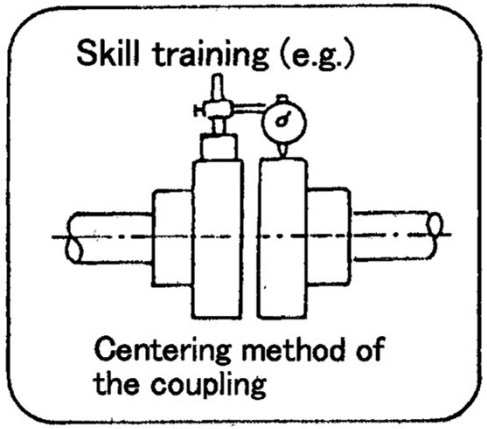
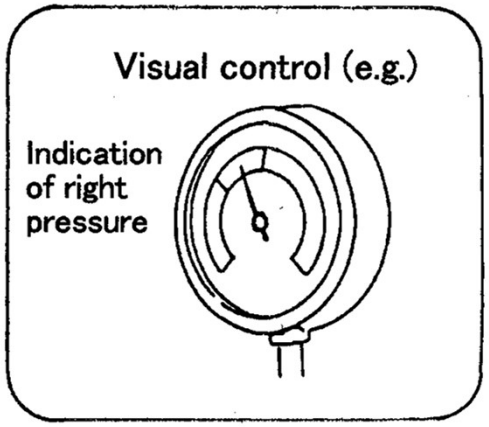
The control valve
Typical assembly of a control valve
The air cylinder
Single acting cylinder
Double acting cylinders
Cylinder mounting
Understanding pneumatic systems
Understanding pneumatic systems
Controlling pressures and flow
Air flow regulating valves
Lubricating the pneumatics system
Air leaks and loose fittings
Repairs to air lines
Creating an inspection schedule

Pneumatics


Unnecessary wiring, hoses
Looseness, dust, dirt, vibration of equipment and pipes
Swing of the needle
Heat, abnormal noise, vibration
Is oil quantity proper?
How dirty is the oil?
Clogging up of the filter


Skill training (e.g.)
Centering method of the coupling


Visual control (e.g.)
Indication of right pressure

Skill level

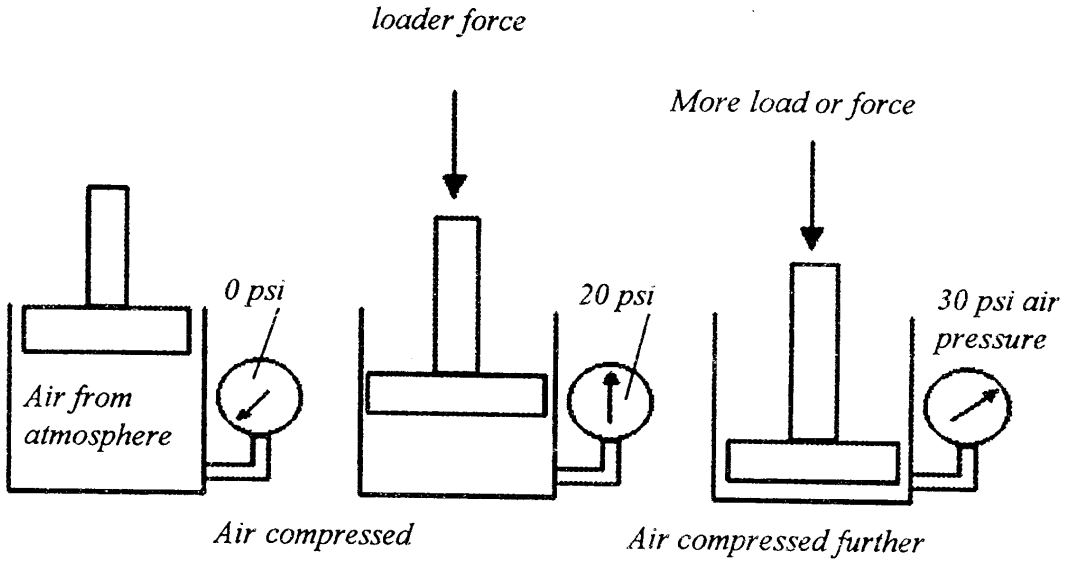
a. Understand how to isolate a pneumatic system and drain off air pressure, so the system is empty.
b. Carry out repairs to pneumatic pipework and fittings.

Extra skill and knowledge operator will require in order to carry out monitoring checks on pneumatic systems: -

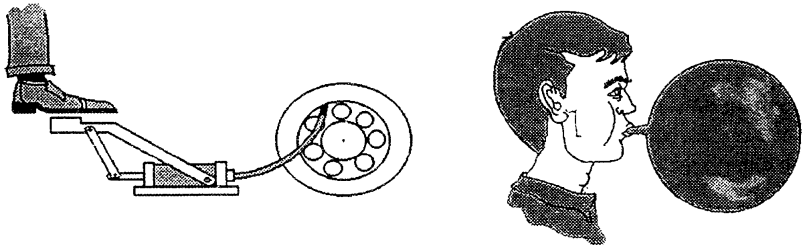
a. Know where the pneumatic system is on the machine.
b. Know how to isolate and drain the system.
c. Have a basic understanding of the function and operation of the pneumatic system.
d. Know how to adjust air pressures to the control setting and regulate an air cylinders speed of travel.
e. Determine the location of air leaks and repair.
f. Create an inspection check list for monitoring the pneumatic system on his machine.

Compressed air for a pneumatic system.

The word pneumatic means the operation or movement of a component by means of compressed air. Compressed air is essential for the operation of a pneumatic system. Without it the system will not function. Compressed air is created by taking air from the atmosphere we breath and forcing it into a small space. By forcing the air into a small space, the air pressure increases. The more force or load that is used to compress the air, the higher the air pressure increases.

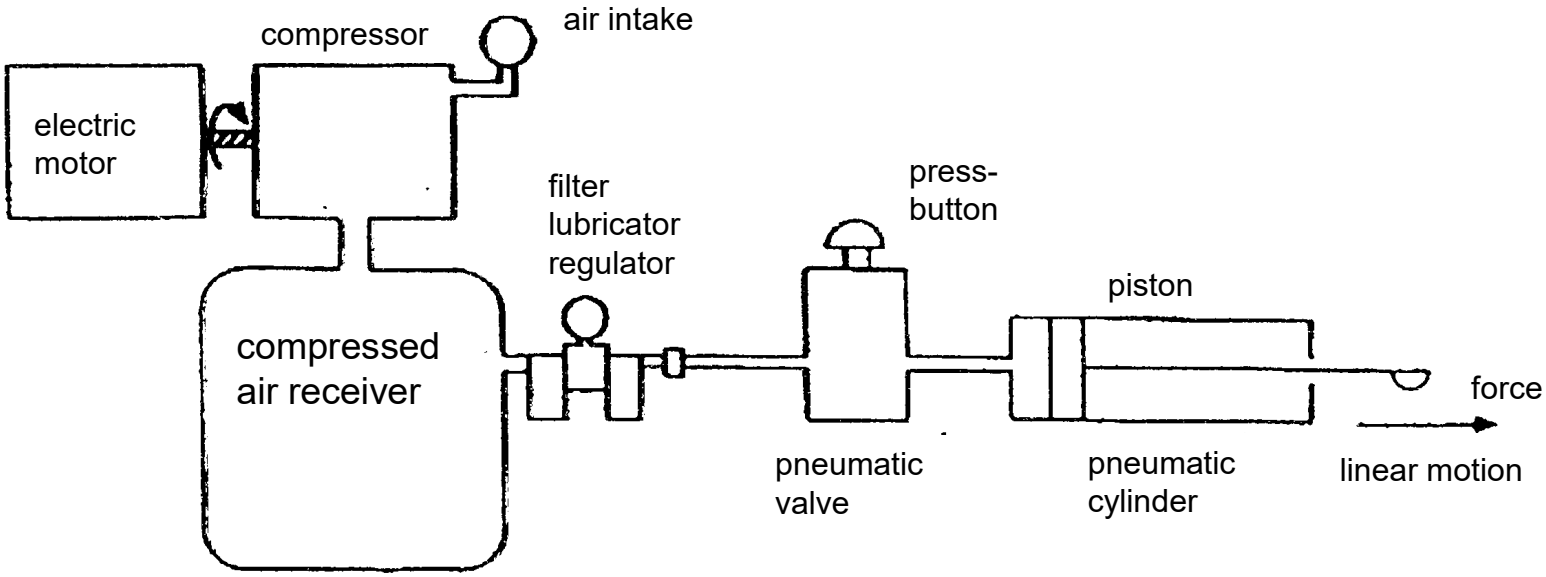


By using a hand pump to blow up a tire or inflating a balloon by mouth, you are creating compressed air.



The pneumatic systems in the factory require much greater volumes of compressed air than this. Large motorized compressor units situated in the boiler house create this greater volume that is needed.

A simple pneumatic system



The air pressure created by the motorized compressor units is stored in a large compressed air receiver tank. From the receiver tank the compressed air is fed through air pipes to each pneumatic system in the factory.

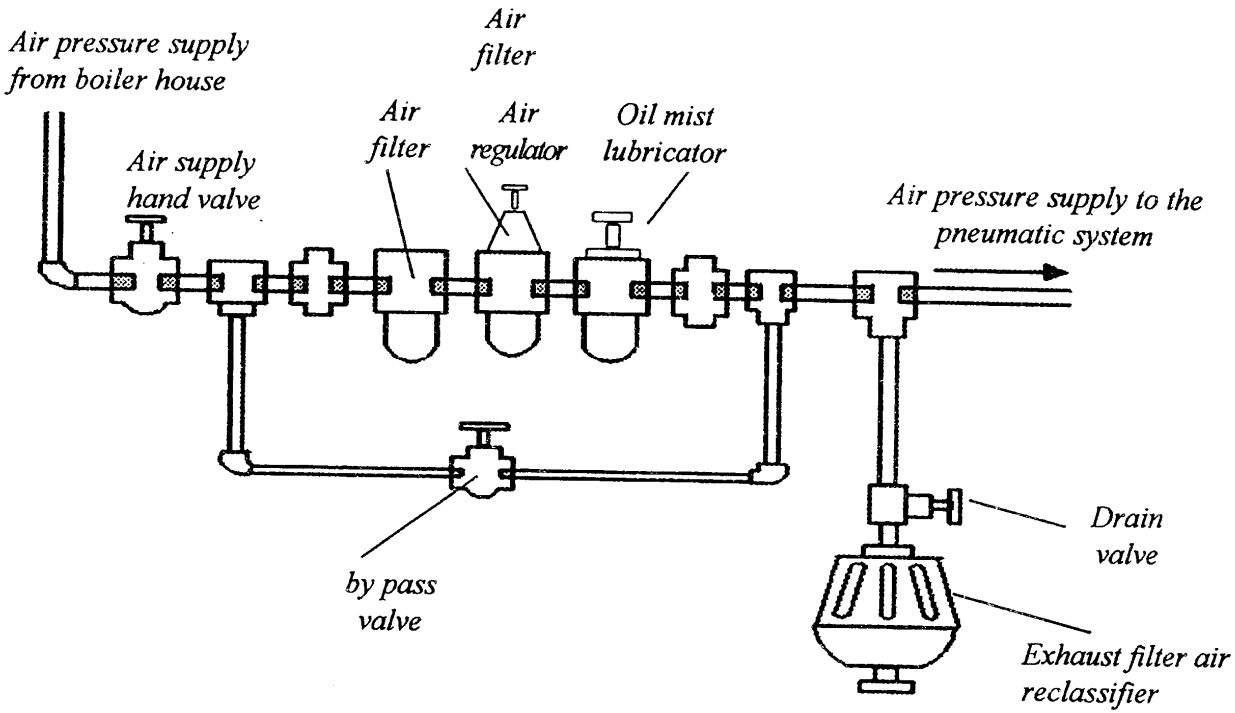
The set air pressure in the air receiver tank is 108 pounds per square inch or 108 psi.

This is the pressure that is fed through all the air feed pipes throughout the factory.

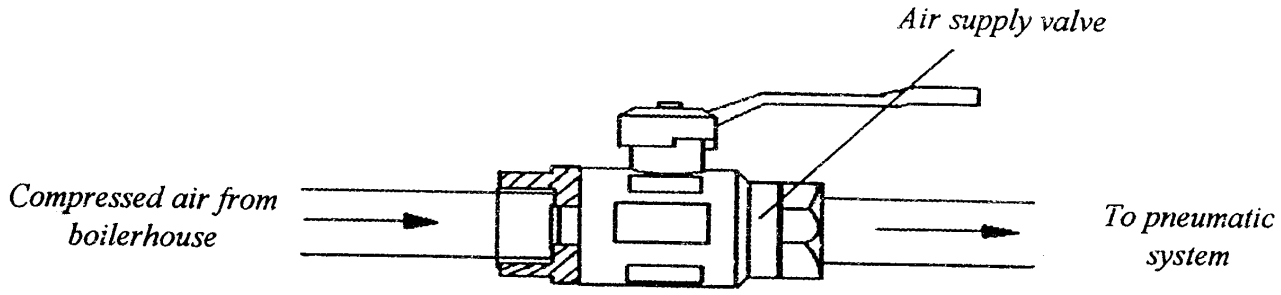
The majority of pneumatic systems in the factory operate at 40 to 60 psi, so the pressure needs to be regulated at the machine.

Filter set for a pneumatic system

An air supply hand valve, a filter set and a hand drain valve must always be installed into an air pressure feed line at the machine, prior to the air pressure reaching the pneumatic system.



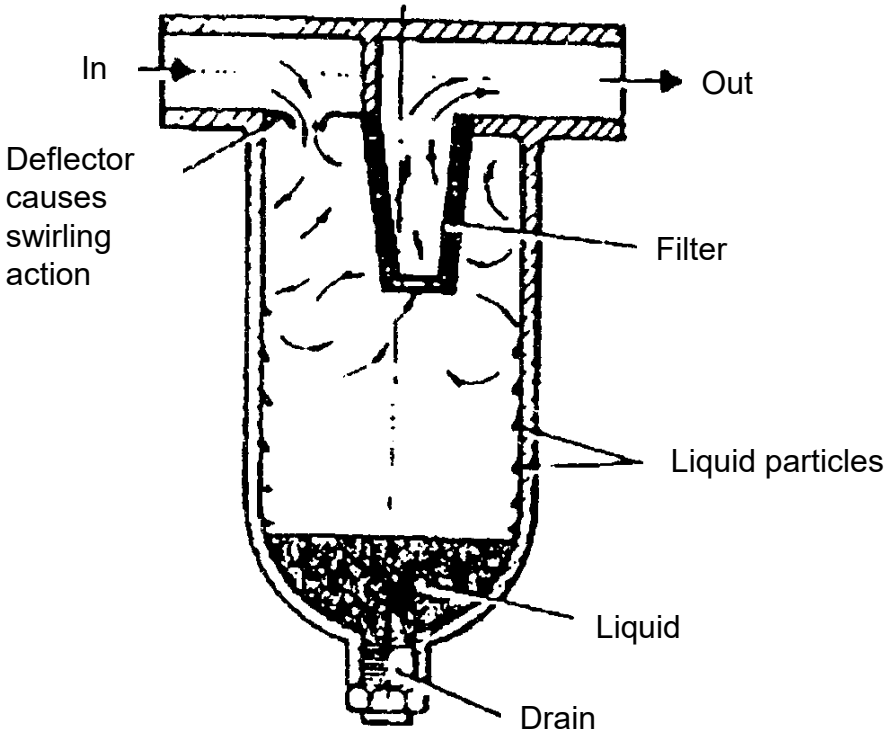
Air supply hand valve. Closing the hand valve will isolate the air pressure from the boiler house to the pneumatic system, so that they system can be drained of air pressure and worked on safely if a repair is to be carried out.



A filter set

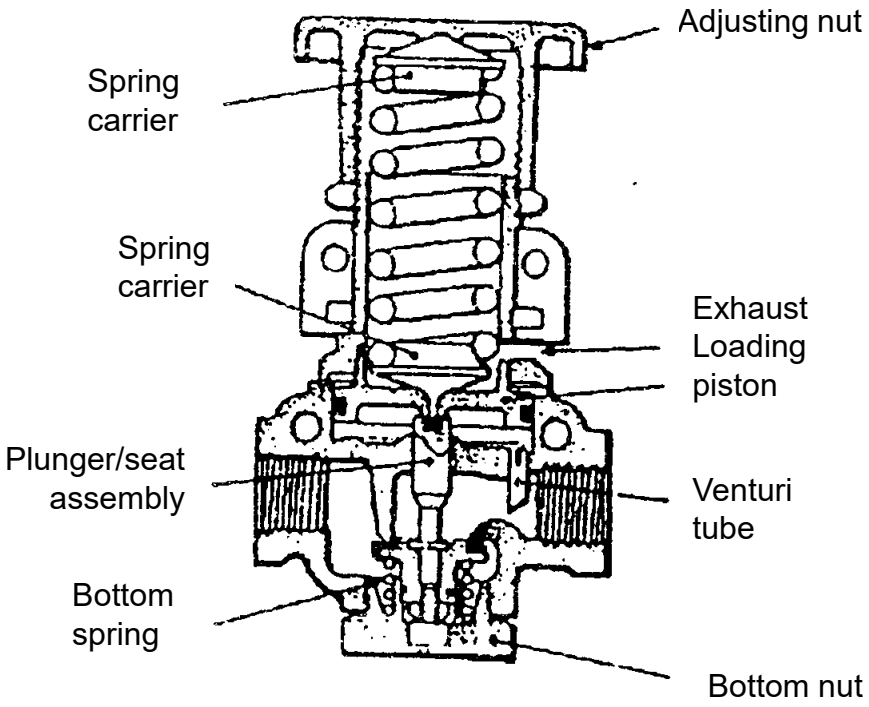
The filter set comprises of: -

a. An air filter. This traps any grit or foreign bodies that come through with the compressed air. It will also trap any water that is in the compressed air. Only clean, dry air goes through the outlet side.



Air line filters include an air deflector which sets up a swirling action, causing heavier solid and liquid particles to be flung onto the wall of the bowl. The air also passes through a renewable fine mesh filter element which removes the finer particles.

b. An air pressure regulator. Adjusting the regulator will reduce or increase the air pressure within a range of 0-108 pounds per square inch (0-108 psi), so it can be set to the pressure that the pneumatic system operates at.

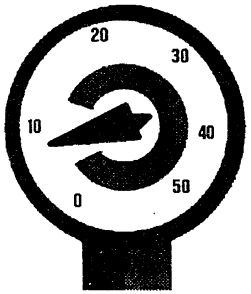


It is often necessary to vary the pressure of air or to ensure that the pressure remains constant. There are a great variety of pressure regulating units. One of these is the pressure relieving type in which a spring loaded piston controls a valve plunger. If the downstream pressure is higher than that set by the loading piston spring adjusting nut, the excess pressure will discharge through an exhaust hole.

There is an air gauge fitted to the regulator, which will inform you of the air pressure that is in the system.

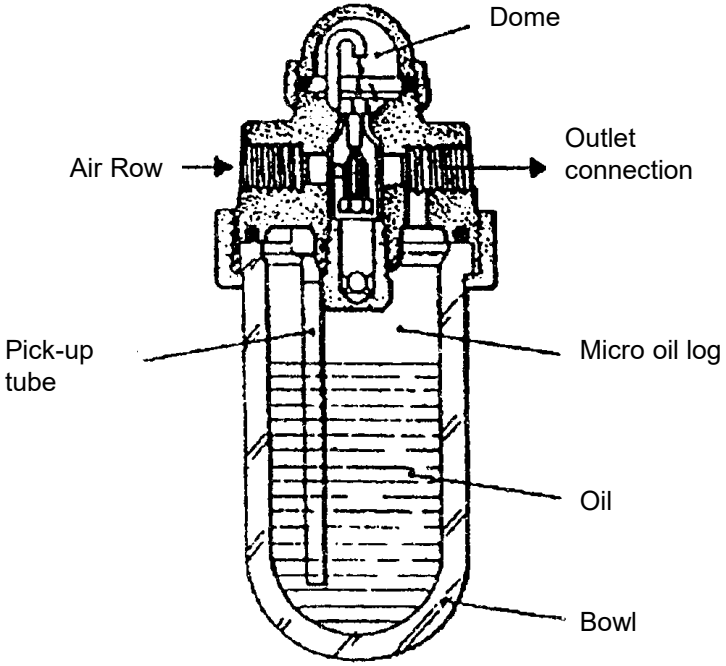
Air gauge

A red ring is attached to the dial of the air gauge. This red ring has a gap in it. When the pointer of the air gauge is set into this gap, the air pressure will be set at the correct pressure for pneumatic system operation: -



An oil mist lubricator

The function of the oil mist lubricator is to feel oil in the form of a fine mist into the compressed air that is moving through the lubricator. This fine oil mist in the compressed air lubricates the insides of all the components on a pneumatic system.

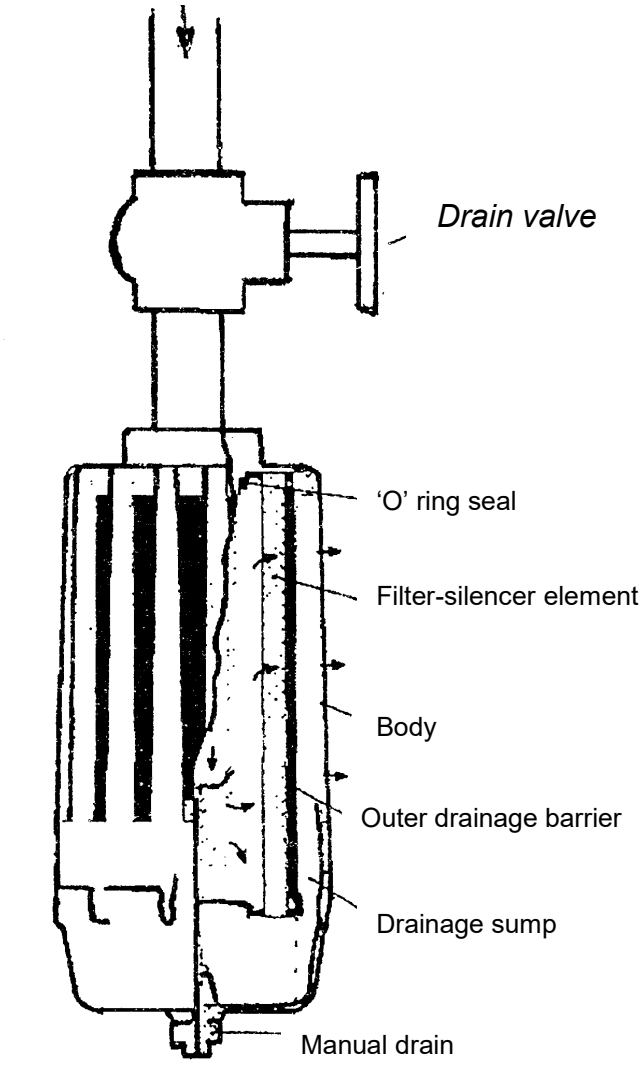


Due to venturi action caused by the flow of air, oil is raised from the bowl into a cavity beneath the dome. A small localized venturi effect causes the oil to disperse into a micro fog which enters the air stream. The unit is manually adjustable so that it may be set for a particular flow rate. At any given setting, the ratio of maximum to minimum flow rate the unit will accommodate is 2:1.

The function of the filter set is to clean, regulate and lubricate the compressed air before it goes into the pneumatic system.

Drain Valve

This is used in conjunction with the air supply hand valve to isolate and drain off the pneumatic system. Because the air pressure in the pneumatic system is contaminated with oil, it has to be exhausted through an exhaust filter air reclassifier. This removes the oil from the air so that clean air is exhausted into the atmosphere.

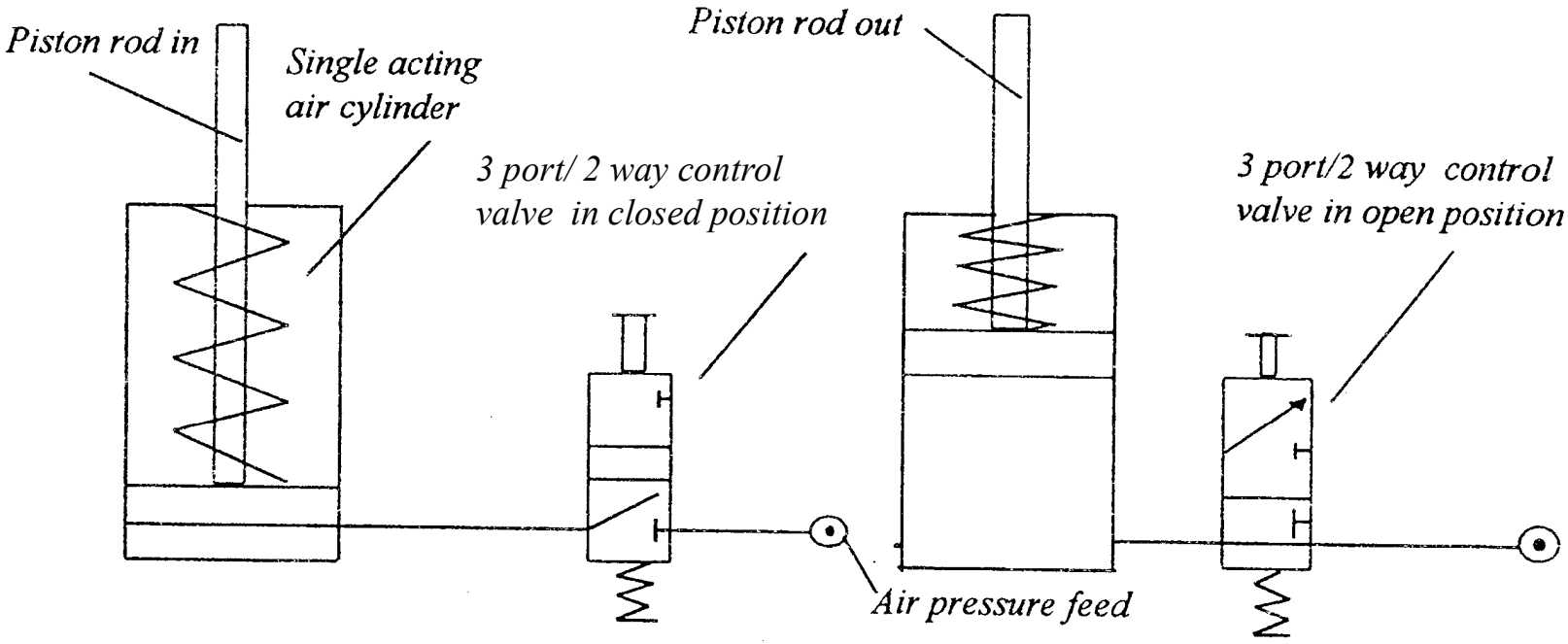


Exhaust filter air reclassifier

Description of a Pneumatic system

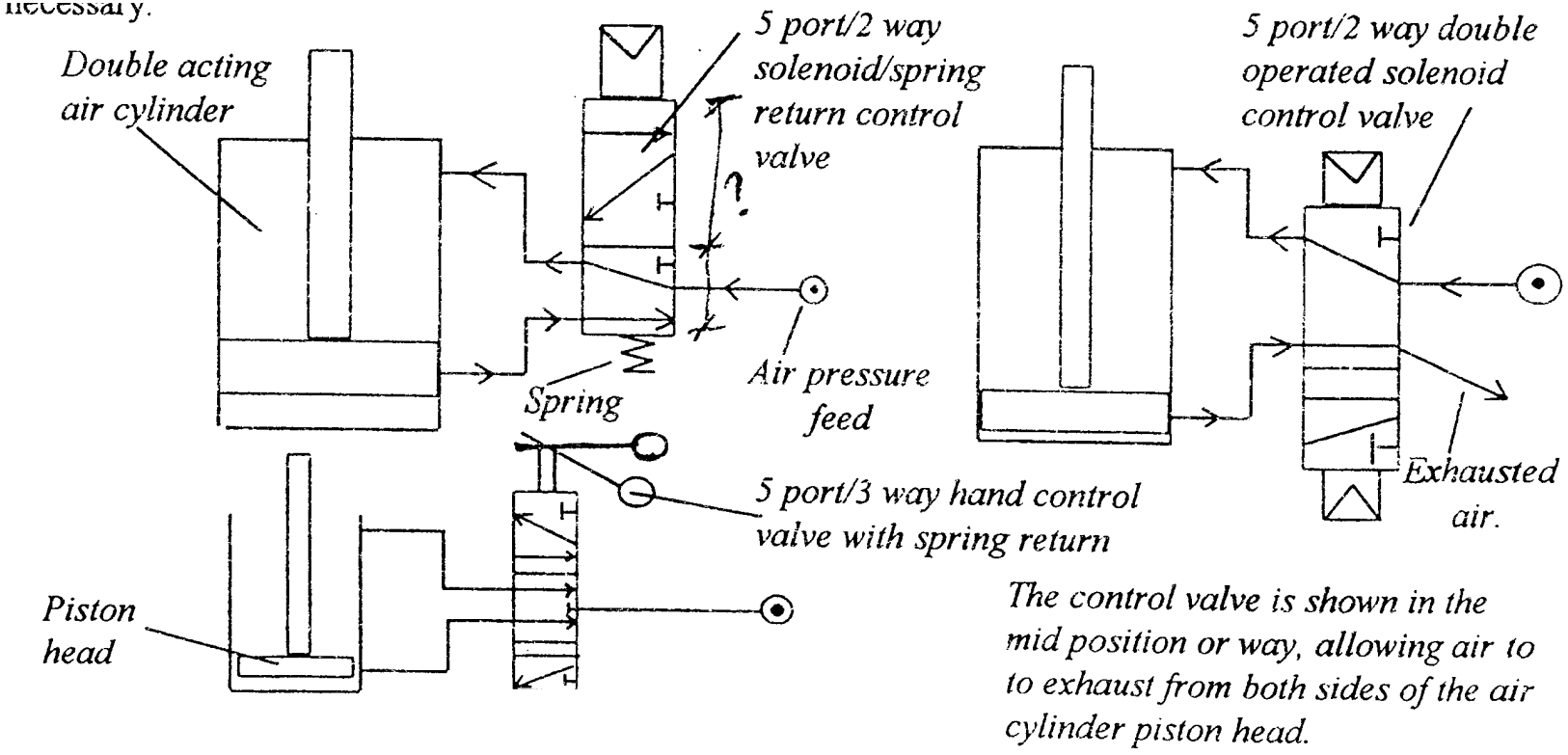
A pneumatic system is a means of transmitting motion and force to move components on a machine. Compressed air is the power source for this motion and force. This compressed air is used in the pneumatic system to operate control valves and air cylinders in order to move components at a controlled power, speed and travel that is required for the correct sequencing of the machine.

The direction control valves serve to order the movement of the pneumatic cylinders. If the cylinder is a single-acting one a three-way valve is required. This in fact, equipped with an entrance port, one for utilizing and one for discharging the air, is able to send the cylinder chamber into pressure and then to discharge it. The requirements of the installation will tell us if the three way valve will have to be normally open, and what the control unit device of the valve itself will have to be.



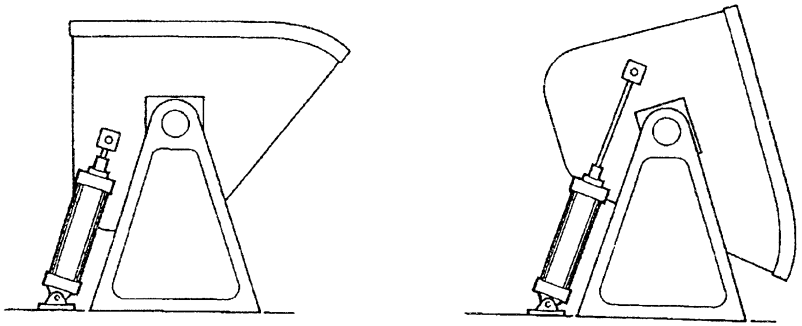
If the cylinder is a double-acting one a five-way valve is required. In most cases five-way valves normally open-closed are utilized, in that theses valves are generally in two positions and it is easy to make the two positions of the pneumatic cylinder connected to the valve correspond to the two positions of the valve. Sometimes however five-way valves normally closed, are used: this happens when a third position in which the cylinder rod is free to move (with both the cylinder chambers in a discharge position) is necessary.

necessary.

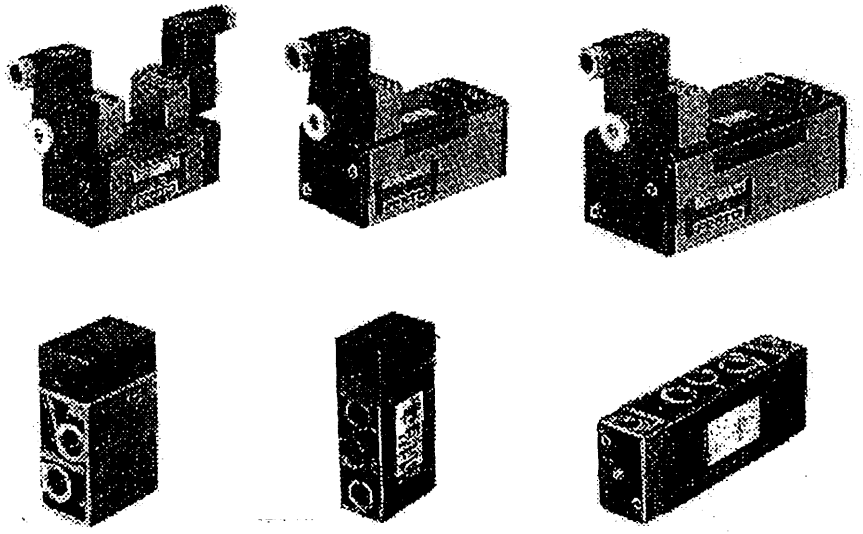


The main component

The main component in a pneumatic system is the air cylinder. It is the prime mover of the system. Its purpose is to convert pneumatic power into linear motion, which is then applied to the machine part that has to be moved.

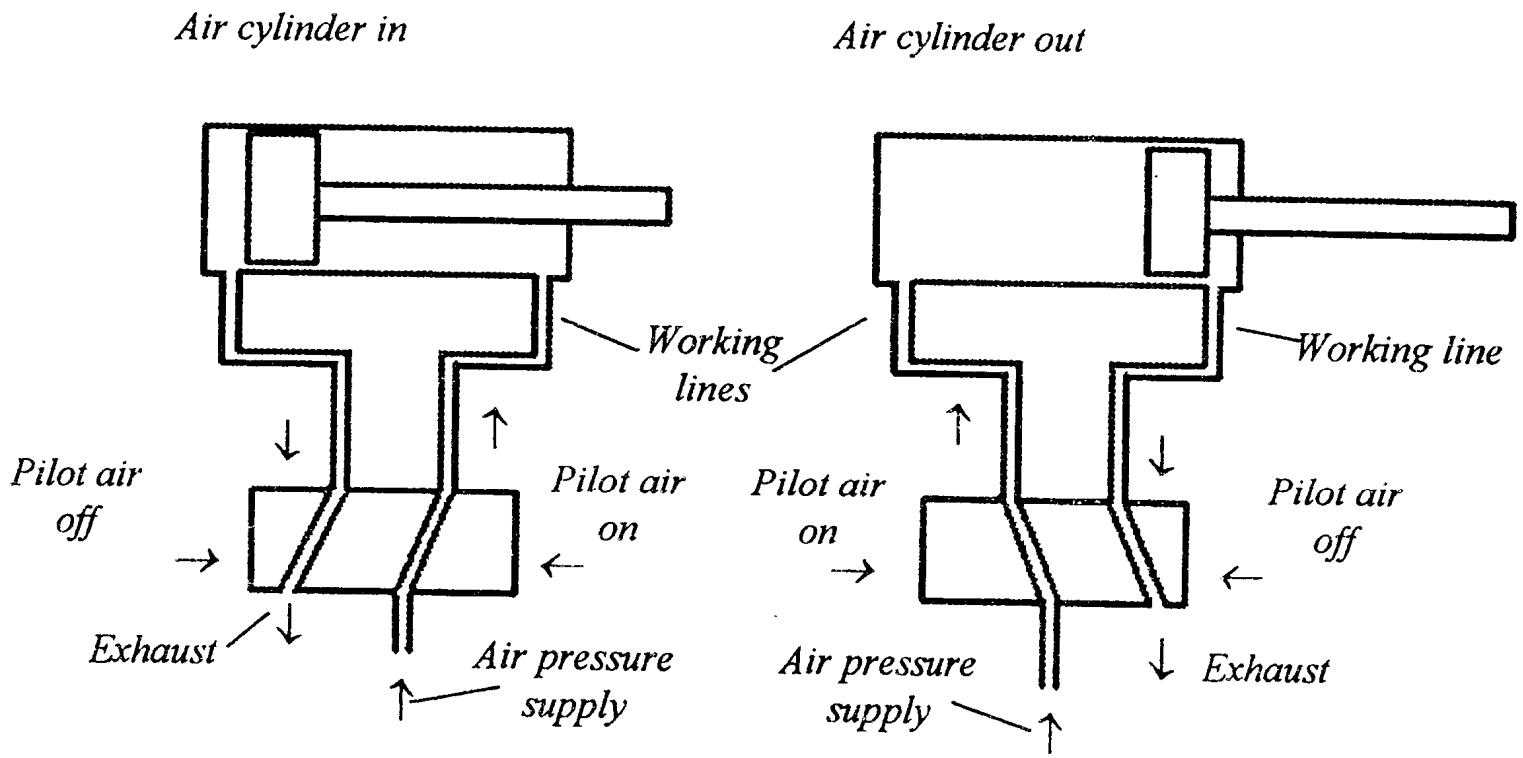


The rest of the components in a pneumatic system control the operation of the air cylinder i.e. - The piston rod movement in and out, the speed at which the piston rod moves, the time when it operates and the power it transmits.



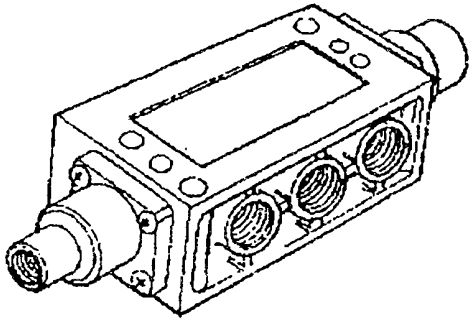
The control valve.

The function of a control valve is to switch over air pressure from one working line to another, in order to move an air cylinder.

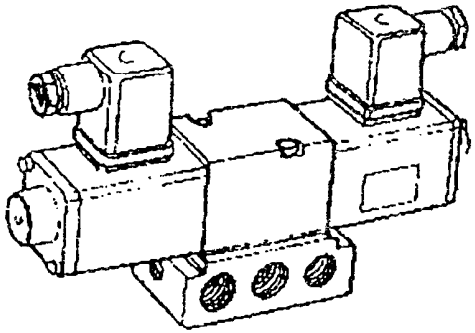


This switching over of the air pressure inside the control valve is done by an actuator.
There are different types of actuators that are used on control valves: -

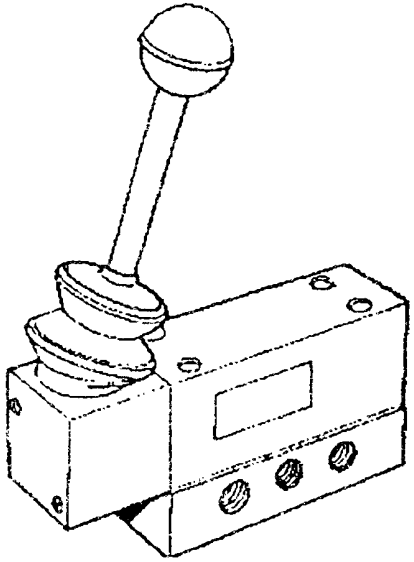
Spool valves may be of the:



* Air operated type



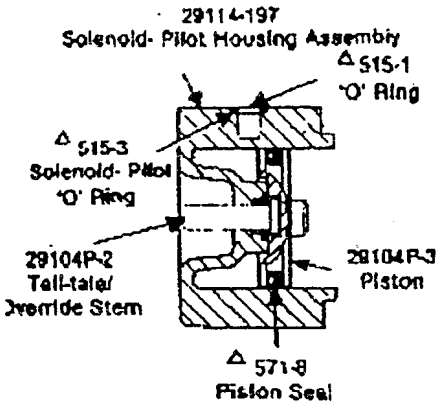
* Solenoid operated type



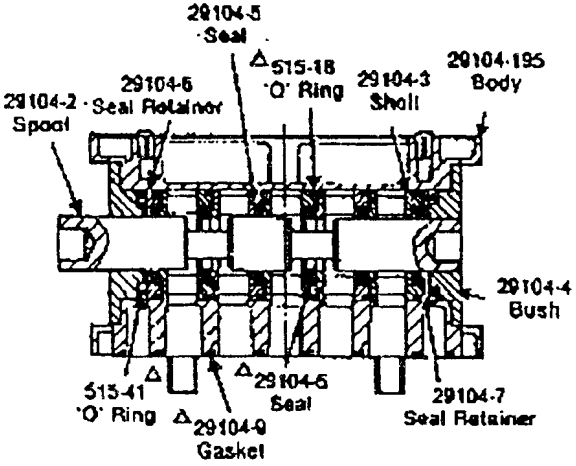
* The manually operated type

Typical assembly of a control valve

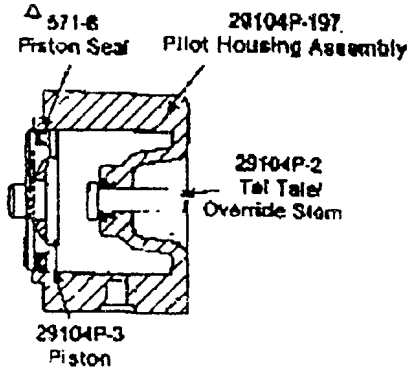
Solenoid pilot operator housing assembly



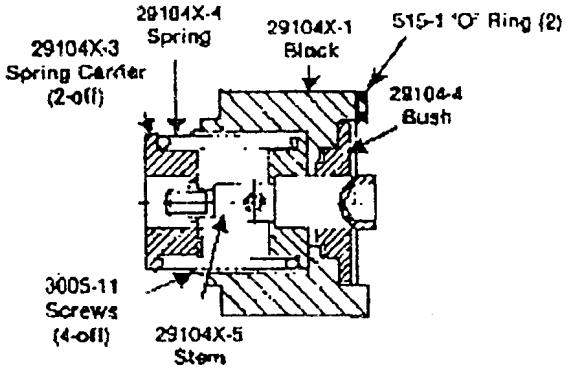
Valve body assembly



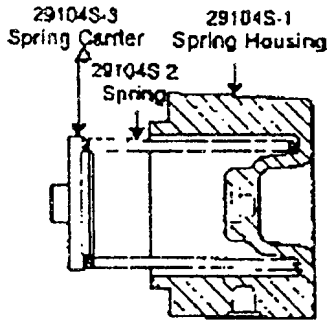
Air pilot actuator or return operator housing assembly



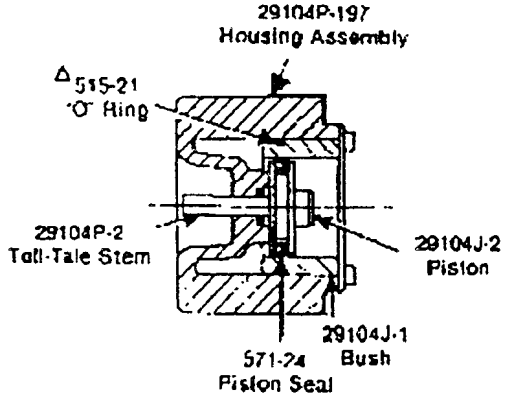
Self centering valve block assembly



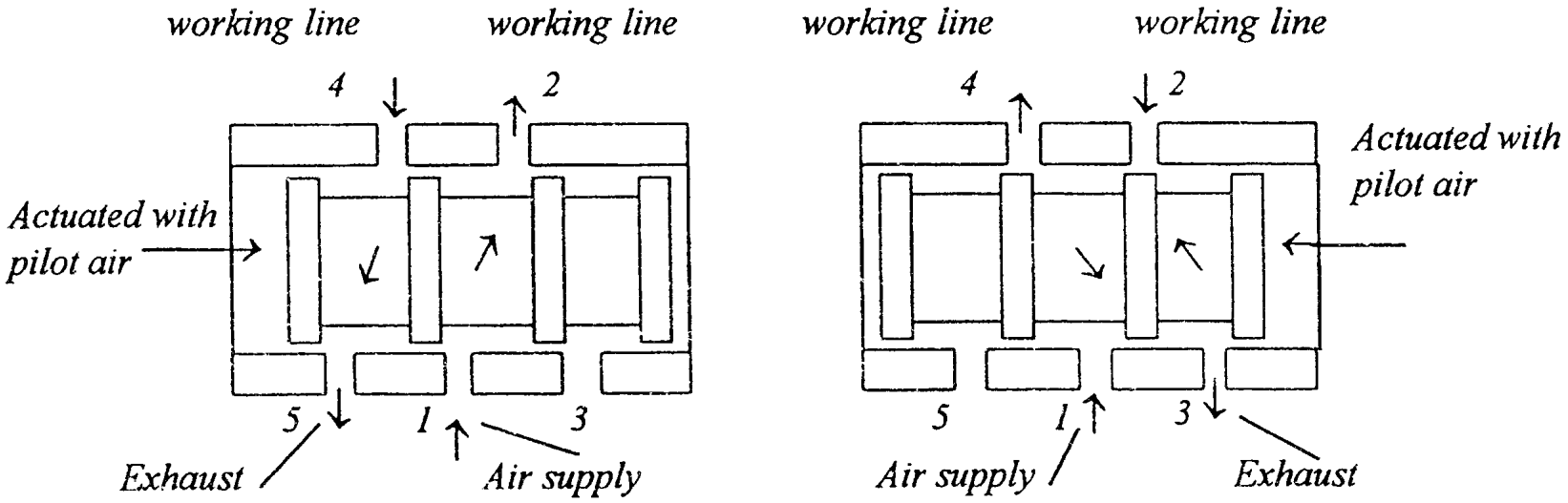
Spring return housing assembly



Differential pilot return housing assembly



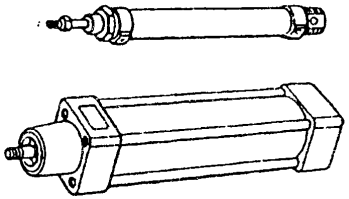
The spool inside the valve, controls which port holes of the valve the air pressure and exhausting air will go through.



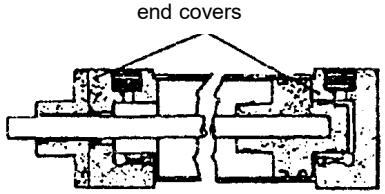
The air cylinder

An air cylinder is basically a cylinder tube fitted with two end covers. Inside the tube is a piston head with and extended rod. The rods extend through one of the end covers. This rod is called the piston rod. There are screwed port holes in both the end covers for the fitting of air hoses. When one of these hoses is pressurized with air, it moves the piston head the full length of the cylinder tube. The exhausting air on the other side of the piston head moves through the other air hose to be exhausted through a control valve or exhaust valve.

The pneumatic cylinder is the prime mover in many installations. Its purpose is to convert pneumatic power into linear motion which is then applied to the machine part or mechanism which has to be moved.

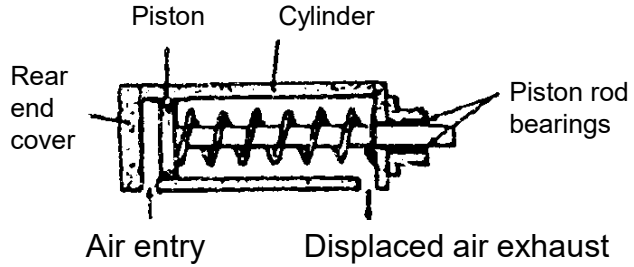


Cylinders range from light duty models to heave duty models.

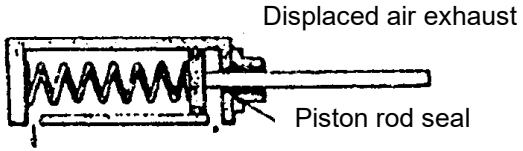


The cylinder assembly comprises a cylinder, enclosed at each end by covers, housing and supporting a piston assembly. The covers are frequently connected together by tie rods. The moving end of the piston rod slides in one of the end covers and it is adapted for connection to the part that is moved.

Single acting cylinder

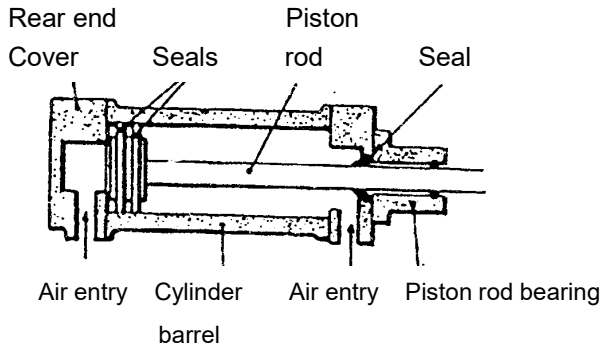


In this type of prime mover, pneumatic pressure is used to drive the piston in one direction only.



The return stroke starts when pressure is relieved and the spring returns the piston to its normal (non-operating) position.

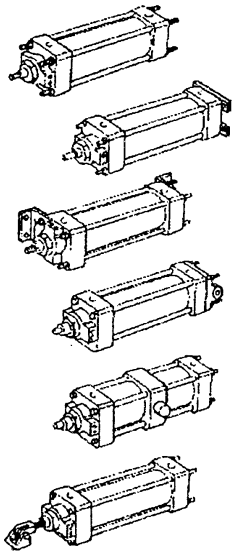
Double acting cylinders



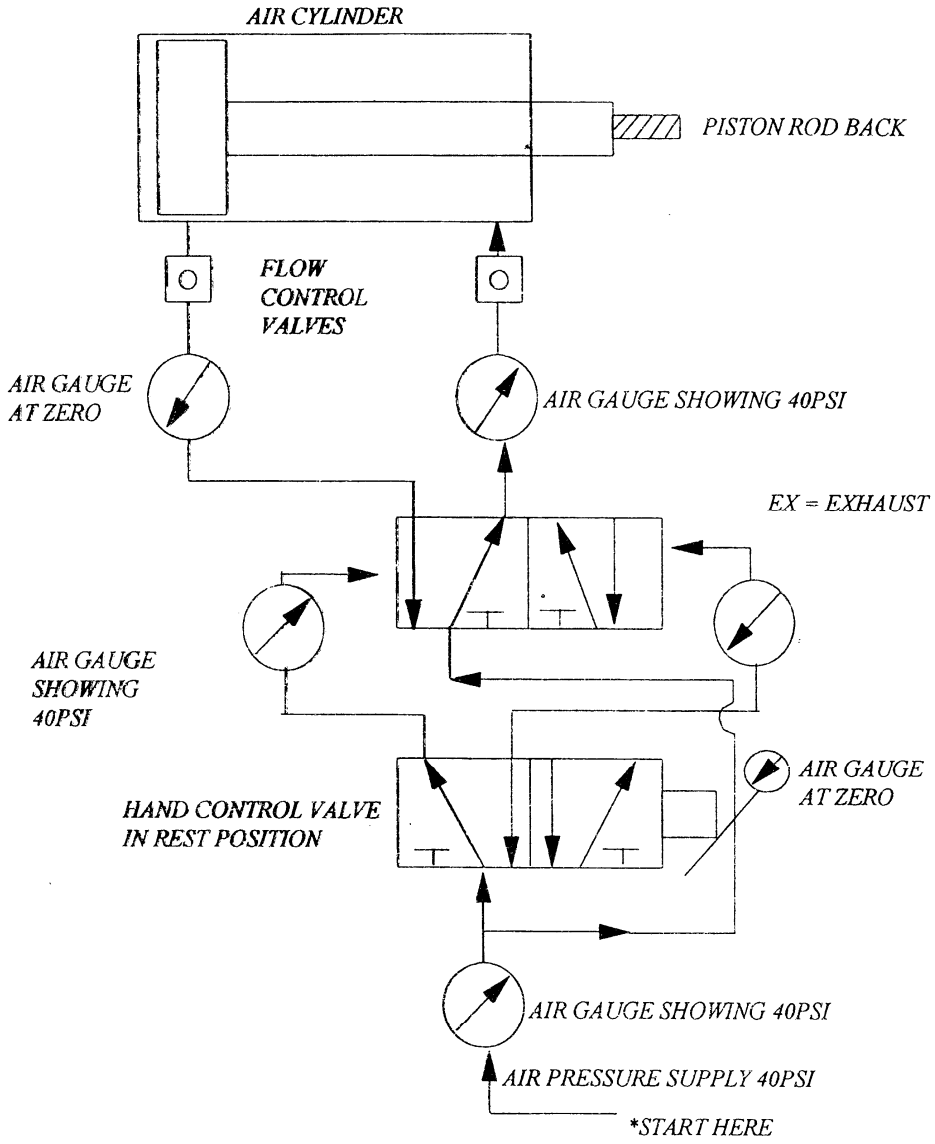
In these units, pneumatic pressure can be directed to either side of the piston to provide forward and reverse full stroke movement or any intermediate position of the piston rod.

Cylinder mounting

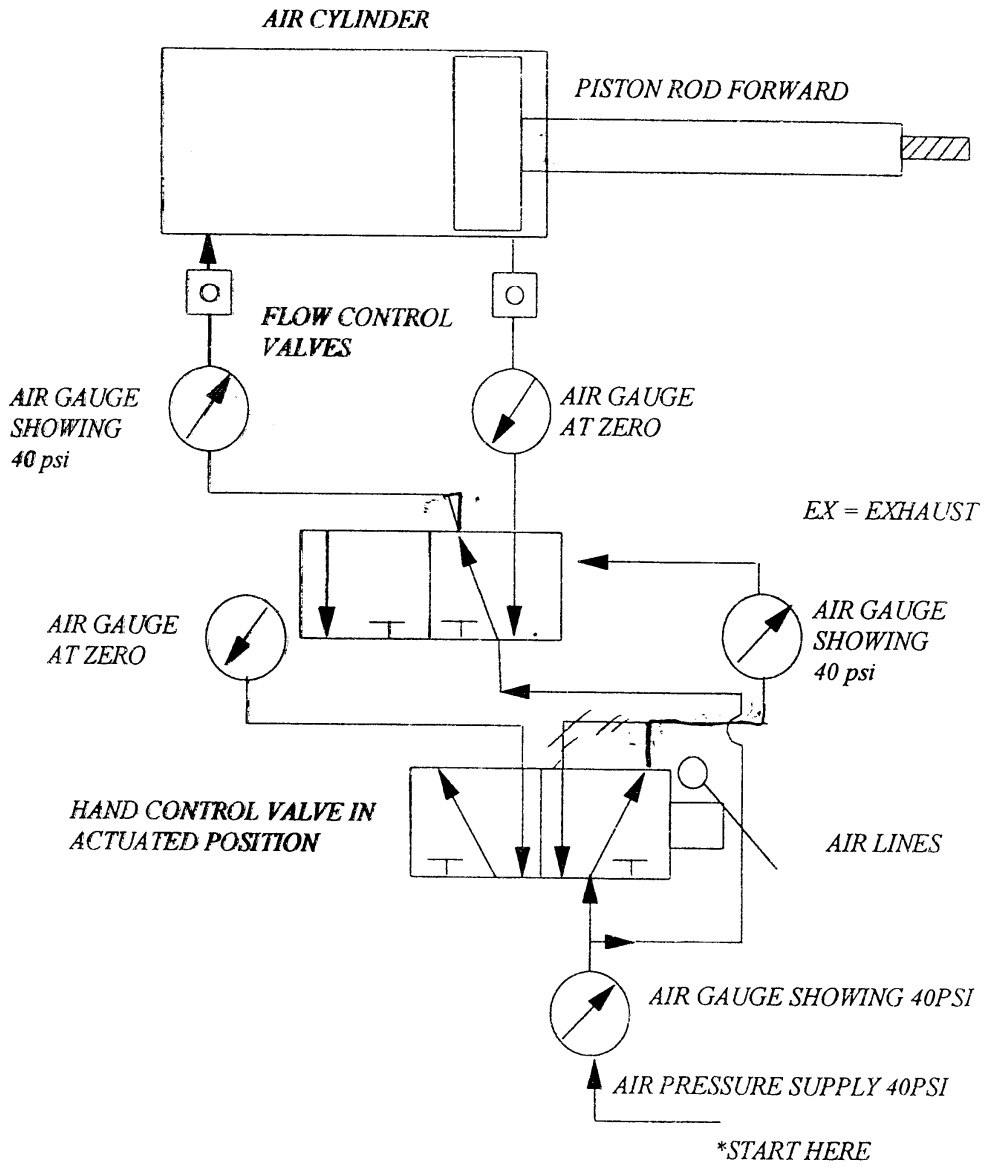
There are many methods of mounting cylinders. In all cases it is essential that the method employed permits correct alignment without subjecting the unit to side loads.



Understanding pneumatic systems



By following the arrows on the air lines, you can trace the route of the air pressure. The drawing is showing the hand control valve in the rest position and the air cylinder back. *Where does the air pressure go to when the hand valve is actuated?

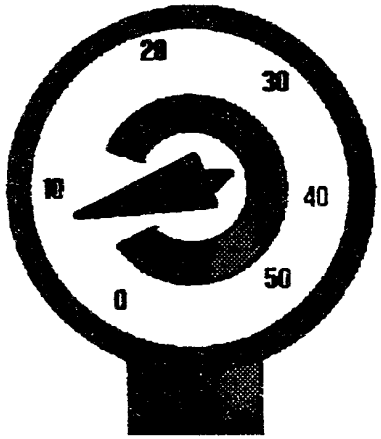


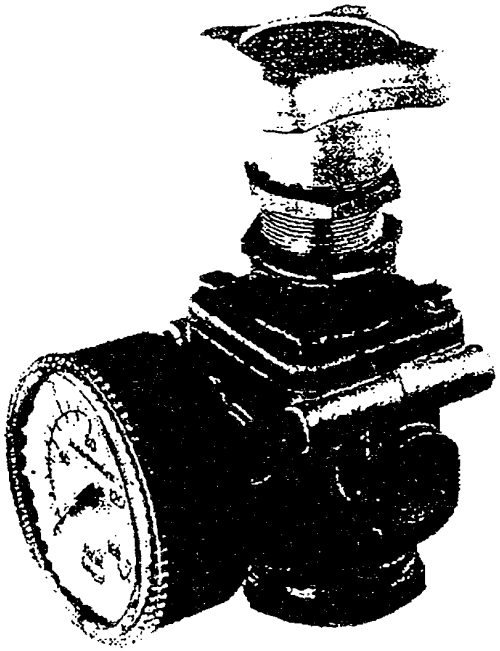
Hand valves has now been actuated. Follow the arrows on the air lines to trace the new route of the air pressure.

Controlling pressures and flow

Air pressure on a pneumatic system are set during the commissioning of a new machine by adjustment of the air regulator. These air pressures are marked up on drawings and manuals and must be adhered to. There may be more than one air regulator in the system. Check and locate them. The regulators must be marked with the correct air pressure they were initially set at.

Pressure Gauge



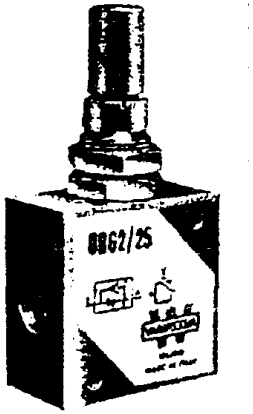


Regulator with gauge

The air gauge must be properly calibrated in order for it to give a correct reading of the air pressure. If the needle does not drop down to zero when air pressure is drained off, then it is out of calibration - renew it. The air gauge is a delicate instrument. It will not stand any rough handling. If there is any damage evident on the gauge - renew it.

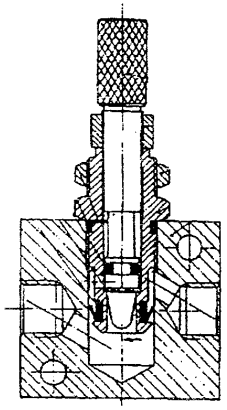
Air flow regulating valves

Air flow regulating valves are used in a pneumatic system to adjust the speed of an air cylinder piston rod in and out. The air flow regulating valve will allow full flow of air pressure into the air cylinder, but will restrict the exhausting air from the cylinder. Two flow regulating valves are fitted to a double acting air cylinder so as to restrict the exhausting air on the forward and back movement of the piston rod.

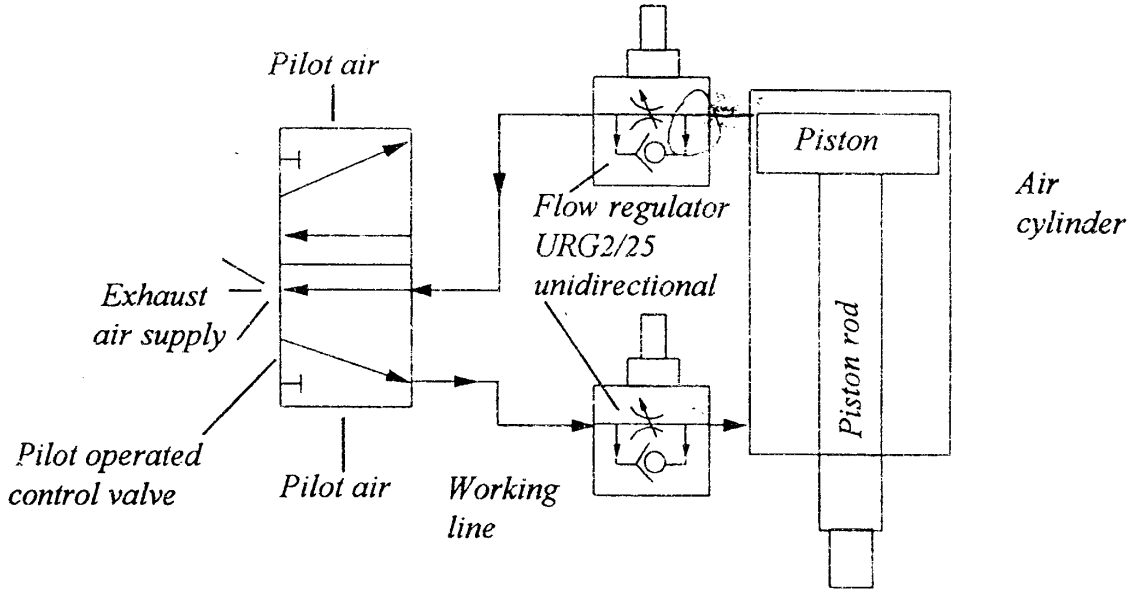


HOW IT WORKS By turning the regulating screw in a right hand direction the regulator [closes] the air passage; it is opened by turning the screw in a left hand direction. The adjustment takes place in just one flow direction; in the other direction the passage is free.

USE Being [in line] the regulators of this series are designed to be installed on a pipeline. Fitted with threaded connections located on the same axis, they are particularly suited for installation on straight pipelines.



FLOW REGULATORS IN PNEUMATIC SYSTEMS

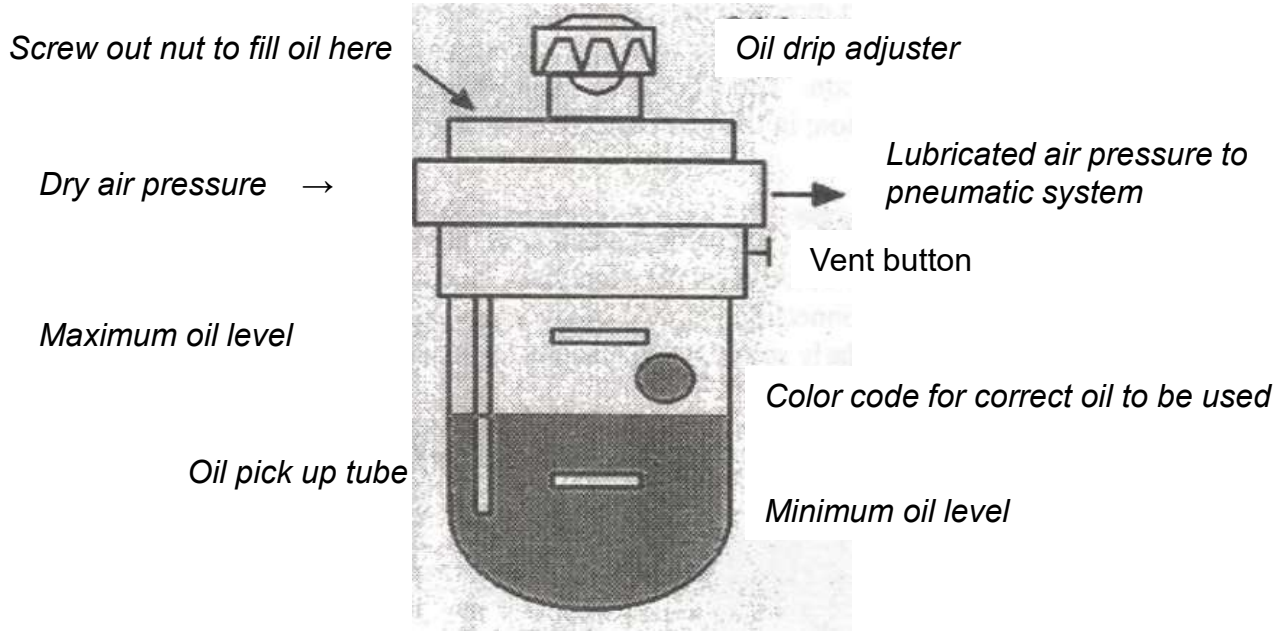


When an air cylinder piston rod requires restricted in its travel, it is adjusted by flow regulator valves that are fitted into the working lines between the air cylinder and control valve. The adjustment is only possible for one direction of flow, while the opposite direction is free flow.

* It is important that these valves are fitted correctly - feed air to the air cylinder is free flow. It is the exhausting air from the air cylinder that is restricted by the flow regulator.
* Do not confuse these unidirectional regulator valves with URF series flow regulators.
  The adjustment is effective in both directions to flow in URF series flow regulators.

Lubricating the pneumatic system

The oil mist lubricator which is on the filter set, puts a fine oil mist spray into the air pressure as it passes through the lubricator. Prior to the oil mist lubricator, the air pressure is known as a dry air system. After the oil must lubricator the air pressure is known as a lubricated air system. This lubricated air lubricates the insides of all the components in the pneumatic system.



The oil used in an oil mist lubricator is Rando HD32, which is a thin golden colored hydraulic oil. Its color code is light blue.

* No other oil is to be used other than this. Other oils will be too thick and will affect the operation of the lubricator.

Check to ensure the oil level drops over a period of days. If it does not drop, than the lubricator is not working. If the oil level drops too fast, too much lubricant will be put into the pneumatic system. You will find the components dripping with oil. The oil drip feed should be approximately two drops per minute.

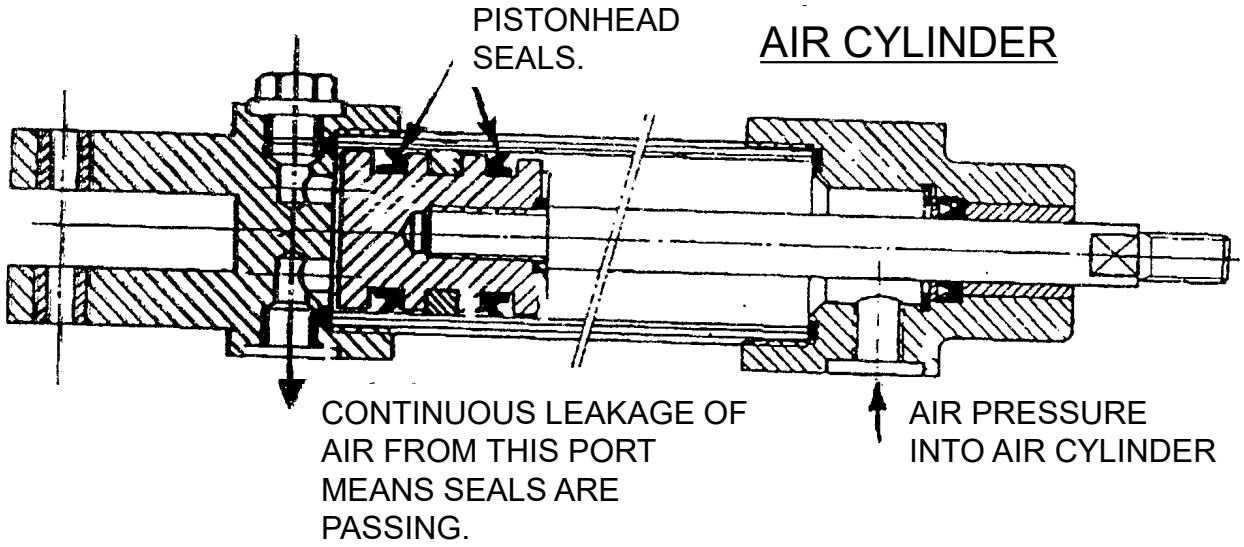
* Never allow the level of oil in the bowl to drop below the bottom of the pick up tube - in this condition the lubricator will not function.

* Always isolate and drain off the air pressure before topping up the oil level.

Air leaks and loose fittings

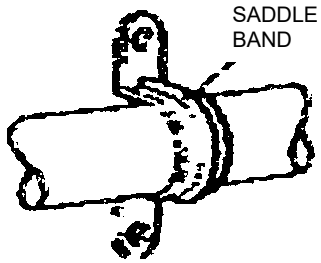
All air leaks on a pneumatic system need to be rectified. This air loss reduces that air pressure on the system and a reduction in pressure means a reduction in transmitted power. An air leak can be heard. Trace its location and rectify. Check control valves and air cylinders for continual leakage of air through exhaust ports. This is a definite indication of seals passing.

Check that all pipework and fittings on the pneumatic system are properly secured. This will reduce war, damage and vibration.



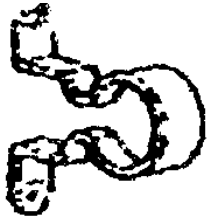
Types of fixing for small bore pipes.

Saddle band



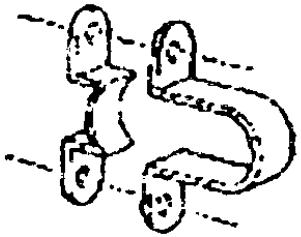
Fitted over the pipe after it has been positioned.

Spacing clip

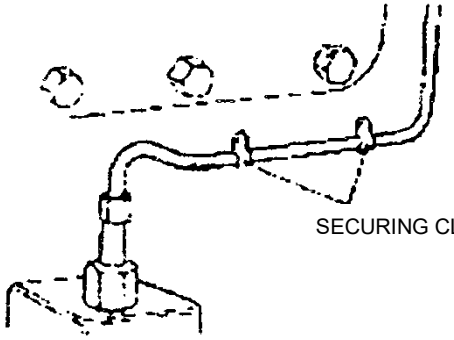


Fitted to the pipe before it is positioned.

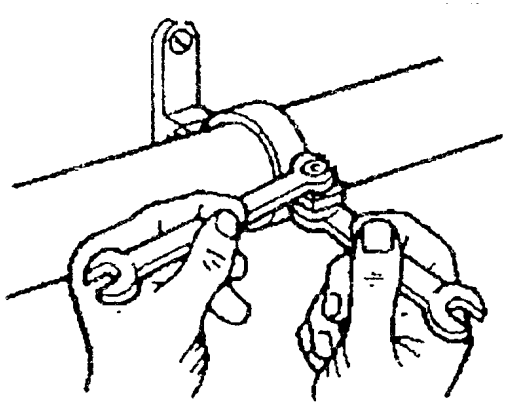
Two-piece spacing clip



The inner part can normally be positioned after the pipe is in place.



Check visually for any obvious signs of damage, e.g. broken pipe securing clips and chafing of incorrectly supported pipes.



Tighten fixings.

Check joints for leaks.

Repairs to air lines

The wade coupling is the compression joint in its simplest form and when correctly assembled, gives a perfect seal that can be broken and remade many times without impairing the efficiency of the joint.

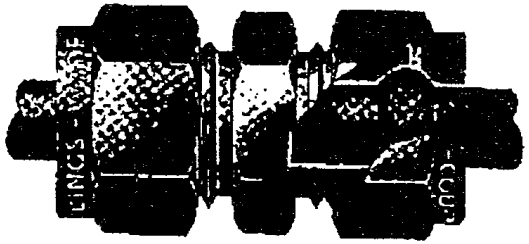
ASSEMBLY 1. No special preparation of the tube is necessary other than ensuring that it is parted off square and free from burrs.

2. Slip the nut onto the tube followed by the copper ring.

3. The tube is then inserted into the body of the coupling so that the tube rests onto the tube adjustment in the body.

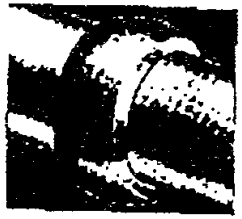
4. The nut is then tightened thus forming a perfect seal. Experience will tell when the perfect compression joint is made as, naturally, the number of turns varies according to diameter and tolerance.

This will be from as little as ½ turn on large sizes to 1½ turns on the smallest diameters. When forming pipework, care should be taken that the bend does not distort the joint after assembly.



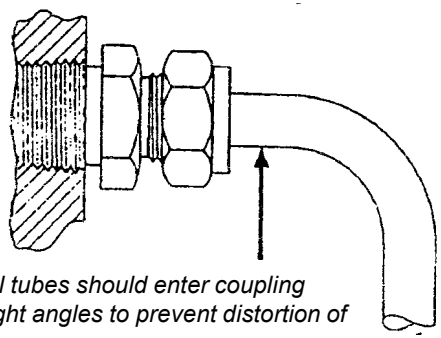
a

This illustrations shows how the copper ring should appear when the perfect joint is made.



b

The burnished mark on the ring indicates where the actual seal is made. This should appear even and unbroken around the periphery of the ring.



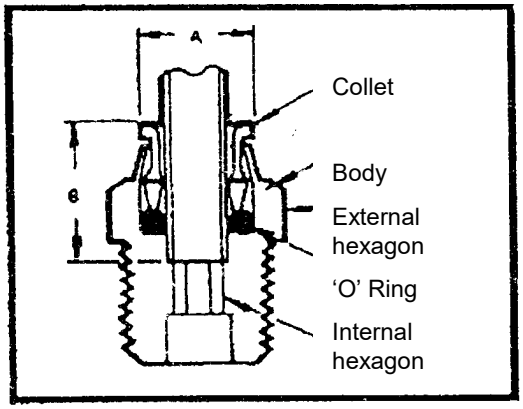
Note that all tubes should enter coupling bodies at tight angles to prevent distortion of joint.

When tightening brass wade couplings, do not overtighten. The copper ring will distort and continually leak. Nip up the nut just enough to tighten down the ring onto the copper pipe and form an air seal.

Tube connection details

Cut the tube cleanly at tight angles and push firmly into the collet. The tube passes through the teeth and 'O' ring to provide a very strong tube connection within a fluidtight seal. To disconnect simply push in the collet with a finger and pull out the tube - no tools are required. Tubing can be connected and released any number of times, but it will be necessary to recut the tubing occasionally to ensure a perfect seal.

Push on fittings for nylon tube



Dimensions (mm)

Tube o.d.	A collect dia	B tube abuttment
4	9	14
5	11	14
6	12	15
8	14	17
10	16	18
12	17	22

IMPORTANT Threaded fittings should be tightened to the following recommended torques.

Thread size BSP	1/8in	1/4in	1/6in	1/2in
Torque Nm	5.6	6.8	9.0	16.9

Creating an inspection schedule

a. All air pressure regulators fitted to a pneumatic system have pressure gauges fitted to record what pressure that regulator is set at. The system operating pressure should be marked by a red circle with a gap on the gauge dial face. The pointer needle of the gauge should always show in the gap when the system is operational.

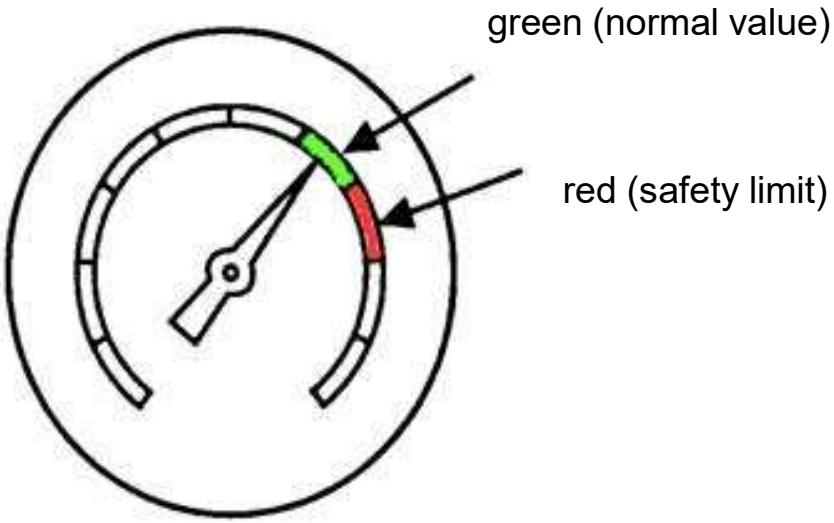
b. Flow restrictors are fitted to the working lines going to an air cylinder. They should be set and locked, the adjusting screw can move - altering the speed.

c. Air leaks on a pneumatic system can affect its performance, delaying the sequence and causing loss of production time. They should be rectified when they occur.

d. Damage to solenoids, control valves etc., will eventually lead to them breaking down. They should be renewed.

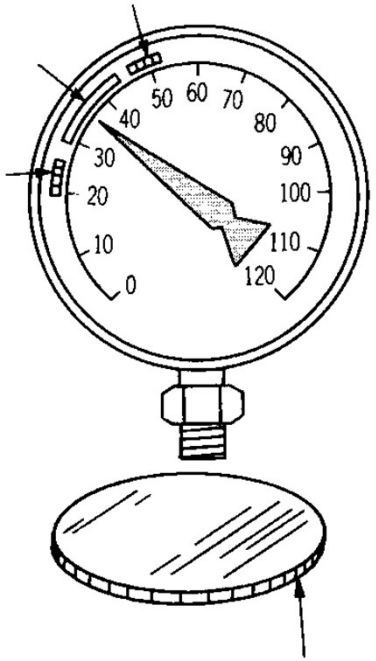
e. Air filters in pneumatic systems need checking regularly to ensure they are reasonably clean and free of water. Any water in the air supply line from boiler house will become trapped in the filter bowl.

Gauge marks



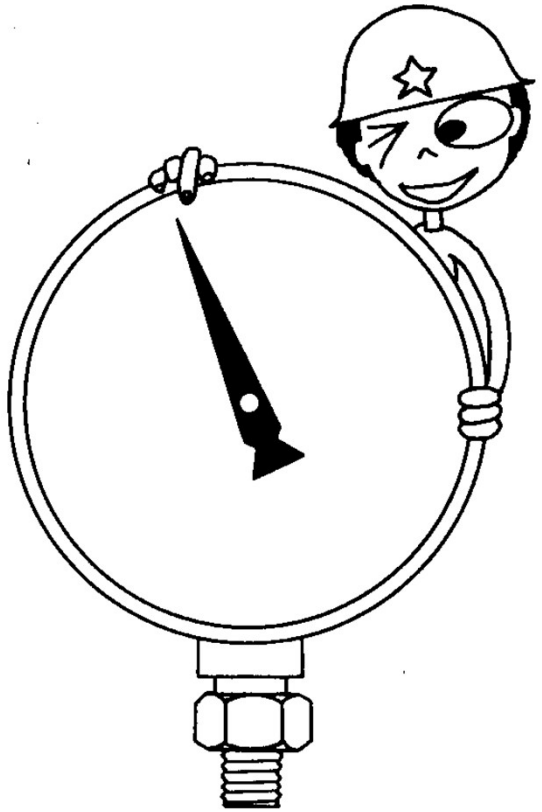
Figure

Do not indicate the pressure gauge limits on the glass cover !

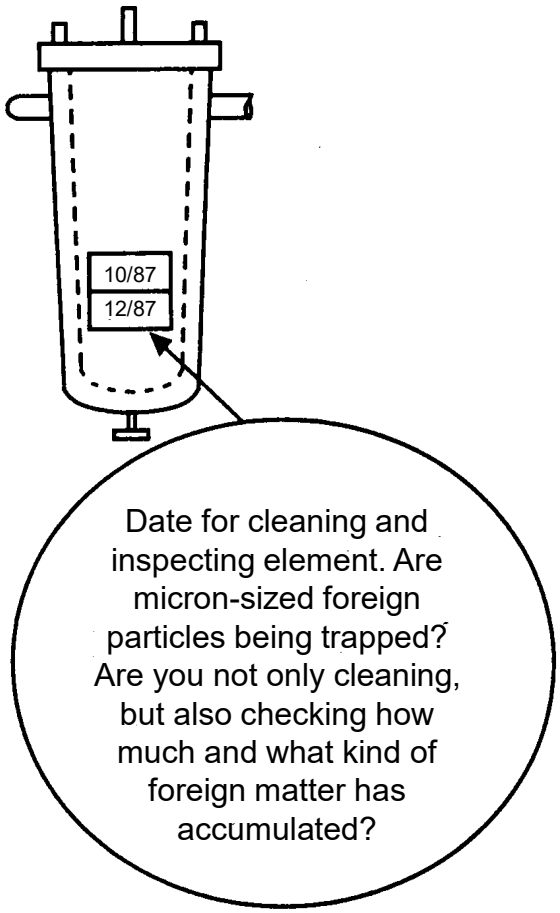


Front glass

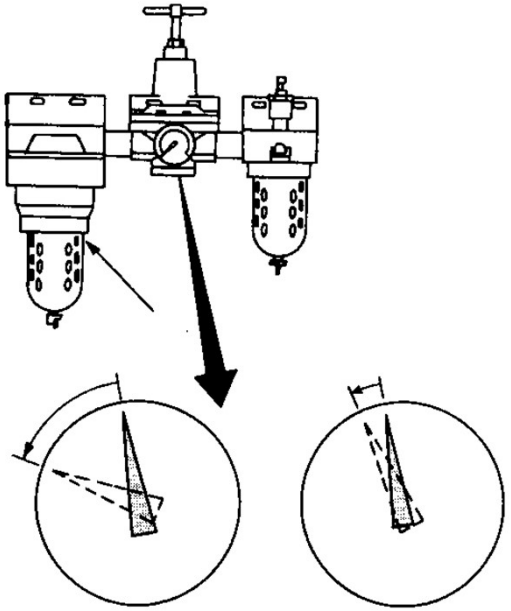
Never let the pressure gauge needle reach the central right-hand position!



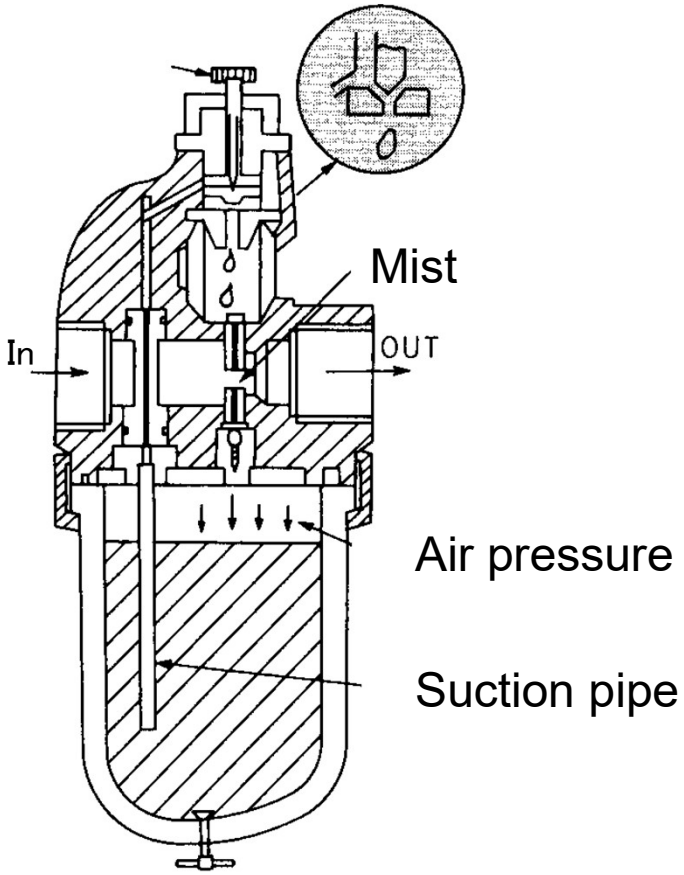
Inspection dates



Do not overlook reduced pressure of an air set of three units !



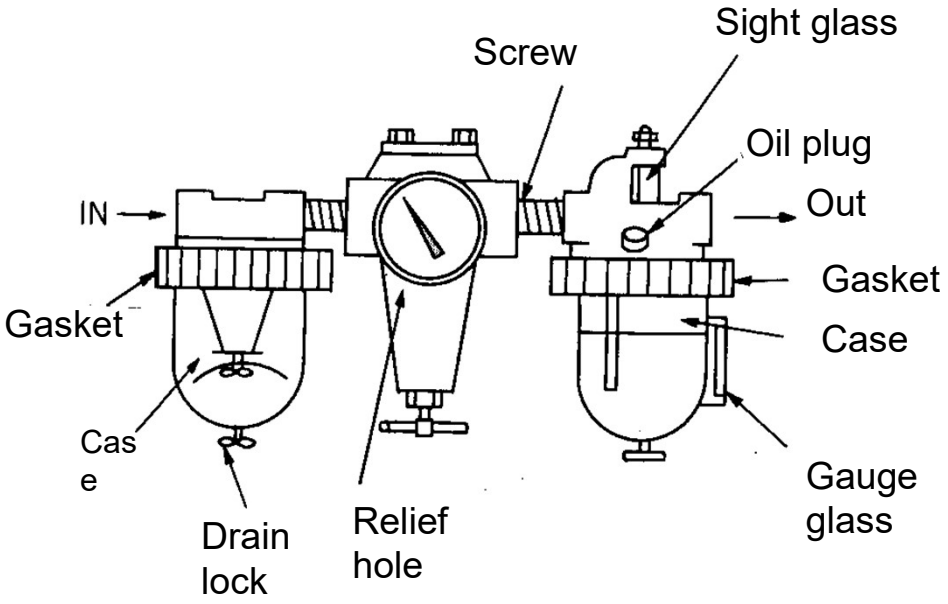
Do not put the lower limit of the oiler below the height of the suction pipe!



Do not leave air leakage of an air set of three units !

Air leakage takes place at the following points :

1. Joint between the units
2. Air relief hole of a pressure reduction valve
3. Gasket of the case
4. Damaged case
5. Damaged gauge glass
6. Oil charge plug of the oiler



Hydraulics

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How the Hydraulic system Works 2
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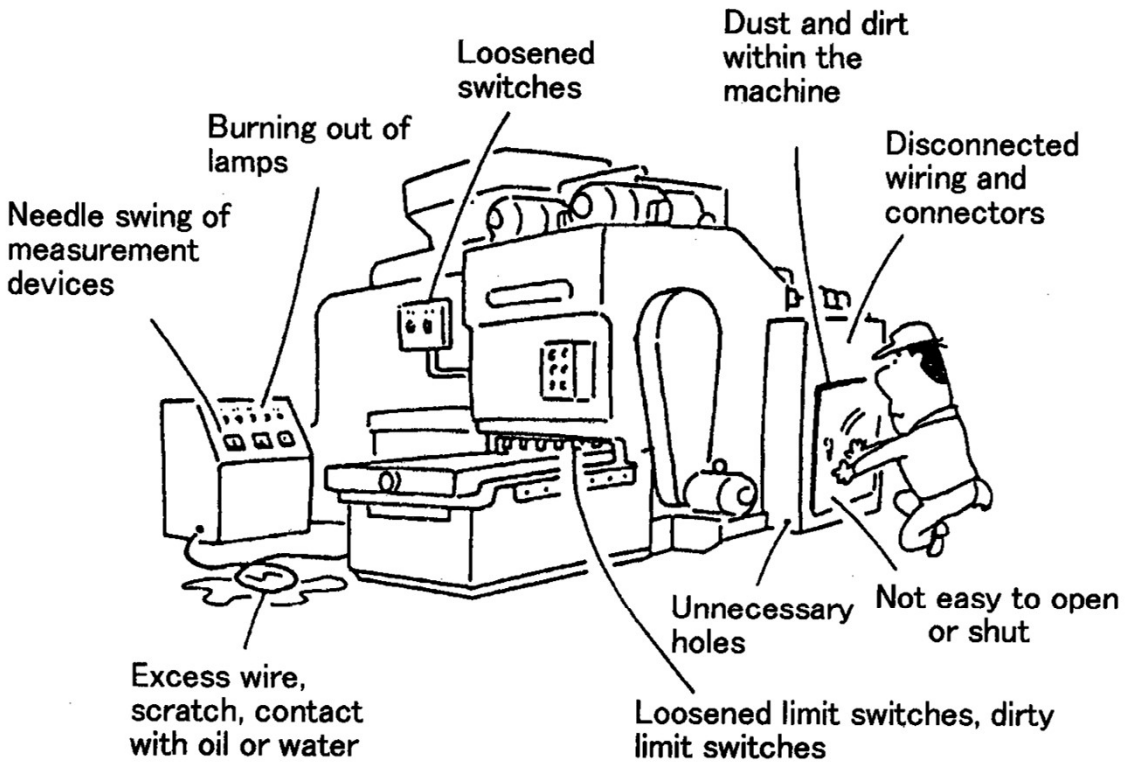
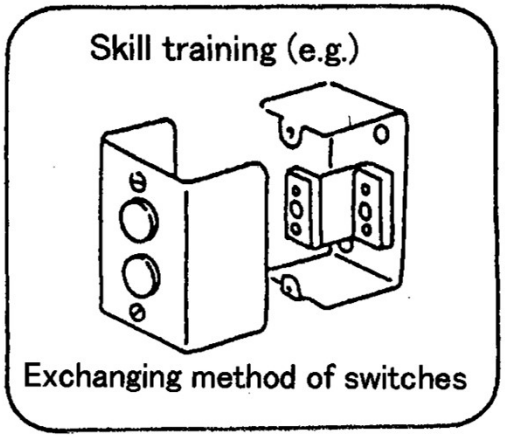
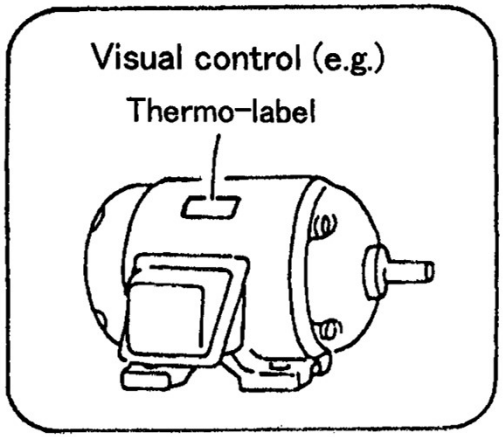
Electricity







Skill Level

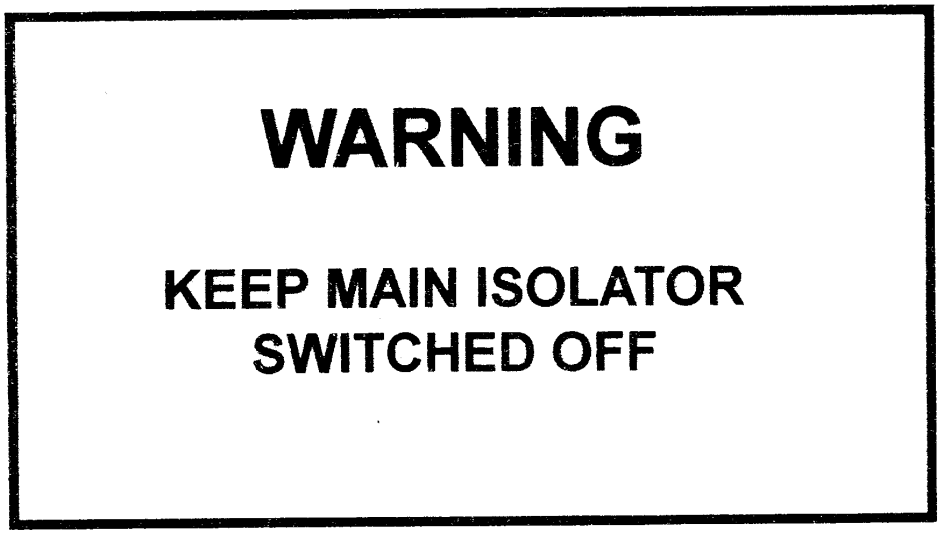
1. Extra skill and knowledge will be required in order to carry out monitoring checks on hydraulic systems.

a. Know where the hydraulic system is on the machine.
b. Realize the importance of isolating the system before carrying out repairs.
c. Have a basic understanding of the function and operation of the hydraulic system.
d. Know how to check the levels and pressures in the hydraulic system.
e. Determine the location of oil leaks and excessive temperature in the hydraulic system.
f. Create an inspection check list for monitoring the hydraulic system on his machine.

Working safely with hydraulic systems

SAFETY - Before breaking any pipe connection or dismantling any component in a hydraulic system:

* Refer to the system drawing.
* Ensure that the pump and pump motor are stationery.
* Ensure that all loads are mechanically propped.
* Disconnect the drive to the pump motor, e.g. if the motor is electrically driven switch off the supply. Have the fuse removed from the appropriate circuit.
* Display an appropriate warning notice.

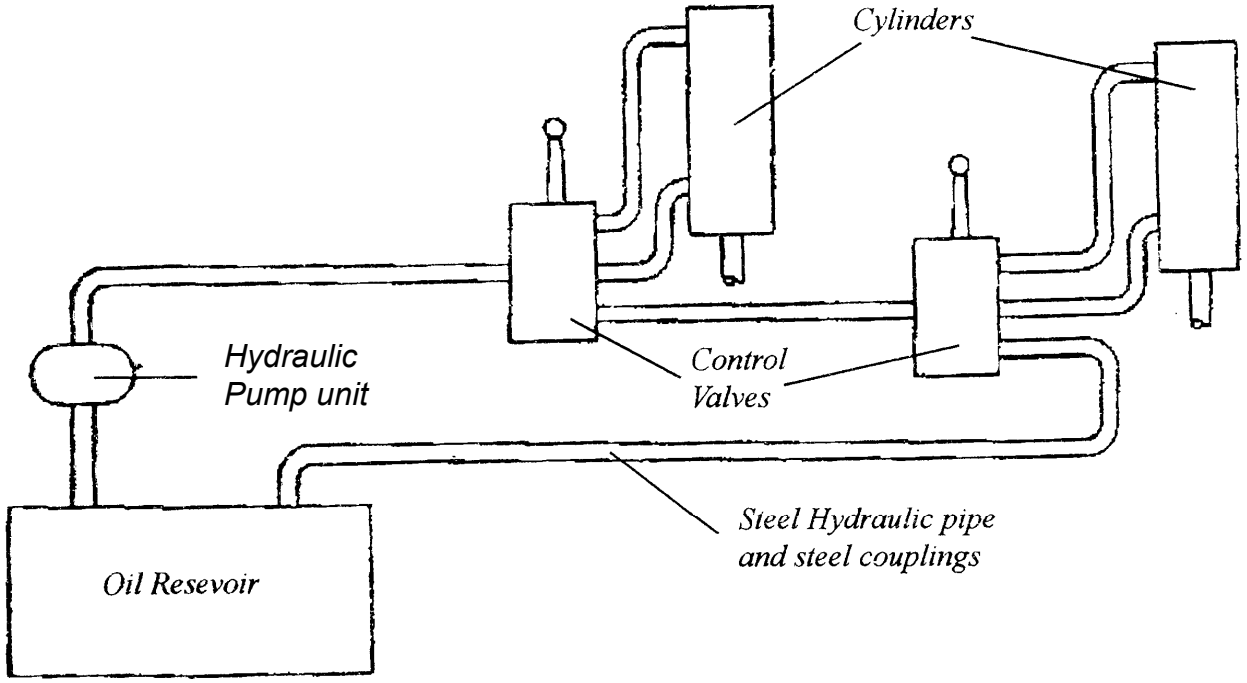


*** Display an appropriate warning notice**

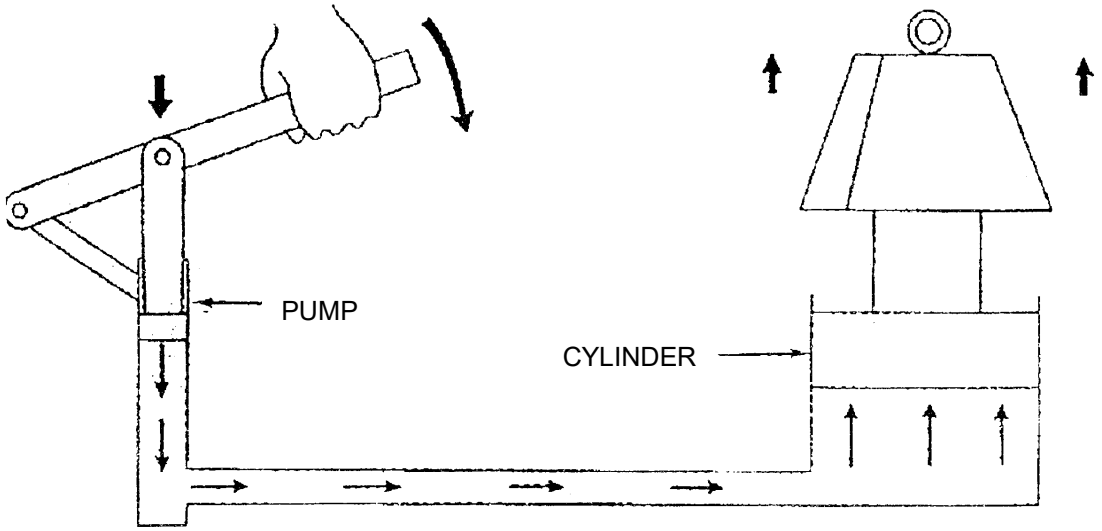
* Do not attempt to slacken or tighten fittings on a hydraulic system while the system is running or when there is pressure in the system.
* Always drain and empty the system before working on it.

What is a hydraulic system?

A hydraulic system is a means of transmitting motion and force to the moving parts of machinery and equipment. In appearance the hydraulic system is similar to the pneumatic system, with cylinders and valves joined up by pipework. But there are differences: - A. Compresses air is used in pneumatic systems as the energy source. Pumped oil is used in hydraulic systems as the energy source. B. In pneumatic systems, the exhausting air is let out in to the atmosphere. It is contained in the system and returned to as reservoir ready for use again. C. The pressures used in a hydraulic system are far higher than pressures used in a pneumatic system, therefore the transmitted force is greater. Consequently the cylinders, control valves etc., for a hydraulic system are stronger and bulkier than the ones used in pneumatic systems. D. Copper pipe and nylon tube are used on pneumatic systems. Steel hydraulic seamless pipe, steel couplings and reinforced hoses are used on hydraulic systems to cope with the higher pressures.

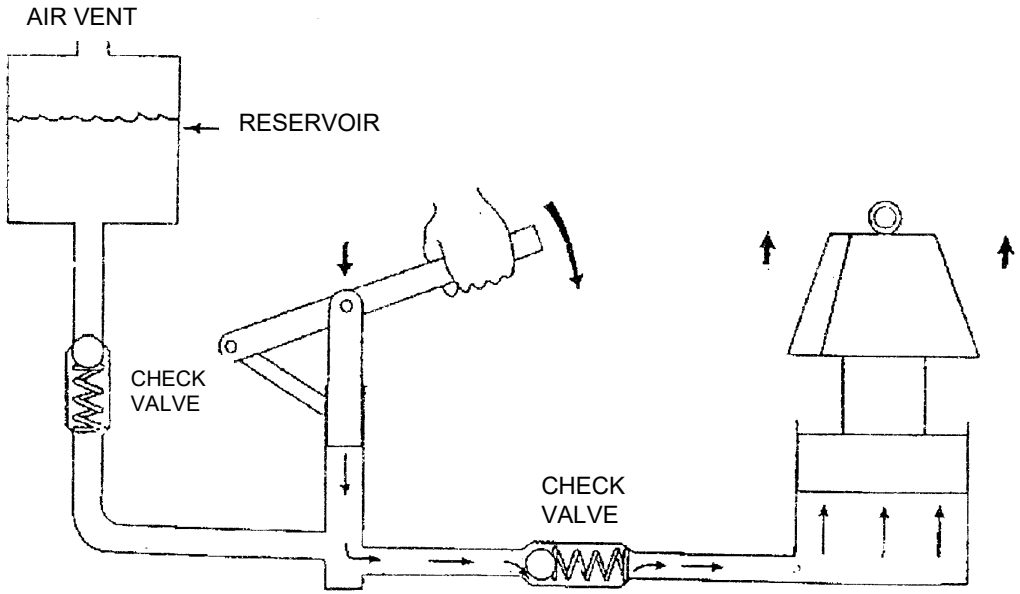


How the Hydraulic System Works 1.



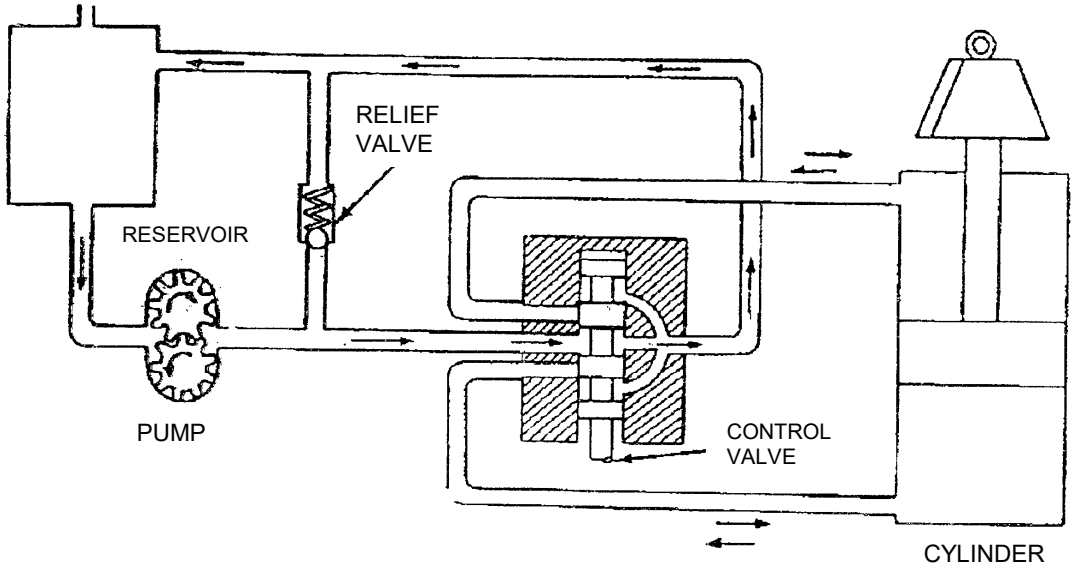
Basic Hydraulic System

How the Hydraulic System Works 2.

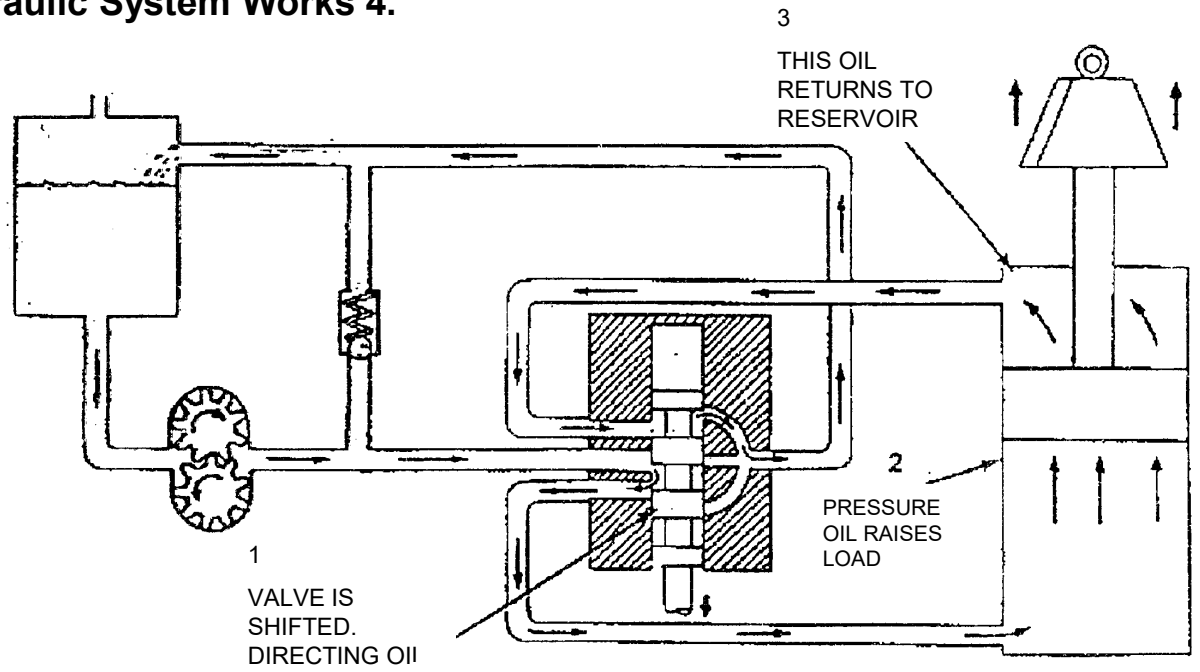


Hydraulic System with reservoir and check Valves Added

How the Hydraulic System Works 3.



How the Hydraulic System Works 4.



Hydraulic System in Operation - Raising a Load

Description of a Hydraulic System

5. Description of a hydraulic system

The basic system consists of: -

a. A fluid reservoir to provide a readily available supply of fluid, to allow time for air to separate to permit contaminates to settle and help dissipate heat.

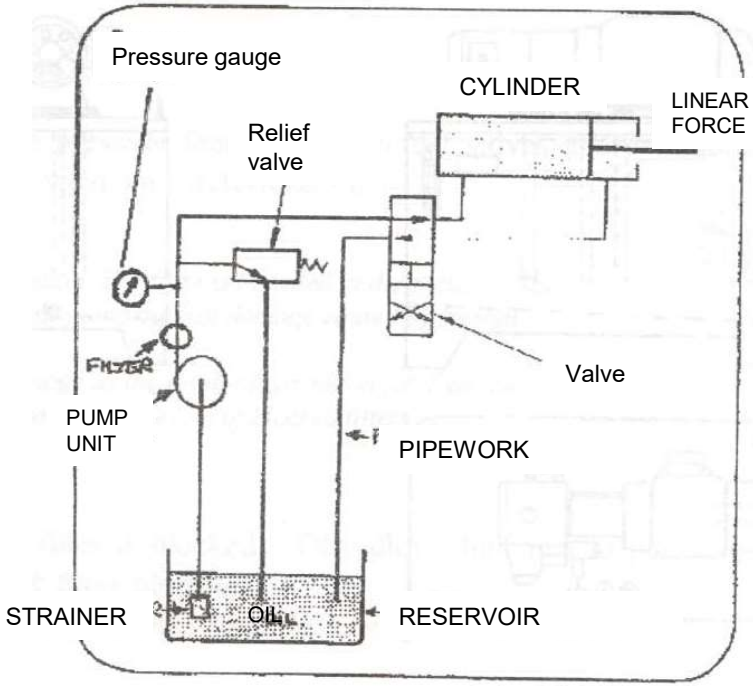
b. A pump or pumps powered by electric motors to create flow of fluid through the system pipework.

c. Valves fitted into the pipework to control pressure and direct the flow of fluid as required.

d. Filters to minimize the effect of contamination entering or being generated by the system components.

e. Pipework to connect all the components of the hydraulic system as required.

Actuating cylinders to give the required linear movement and force to move parts of machinery and equipment.



The Power Pack Unit

The power pack consists of: -

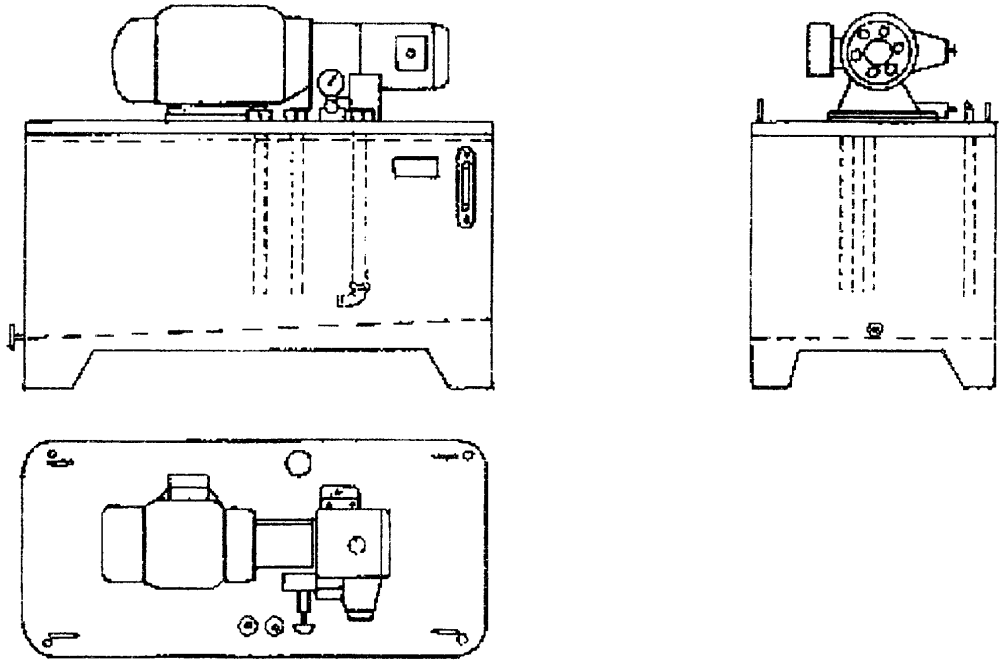
a. A storage tank for the oil, which is called the reservoir. It has a filler cap on the top for replenishing the oil and there is a sight glass on the side of the reservoir to indicate the oil level.

b. A pump unit mounted on top of the reservoir which is powered by an electric motor. Sometimes there are two pump units if two different pressures are to be used in the hydraulic circuit. The smaller one is the high pressure pump and the larger one is the low pressure pump.

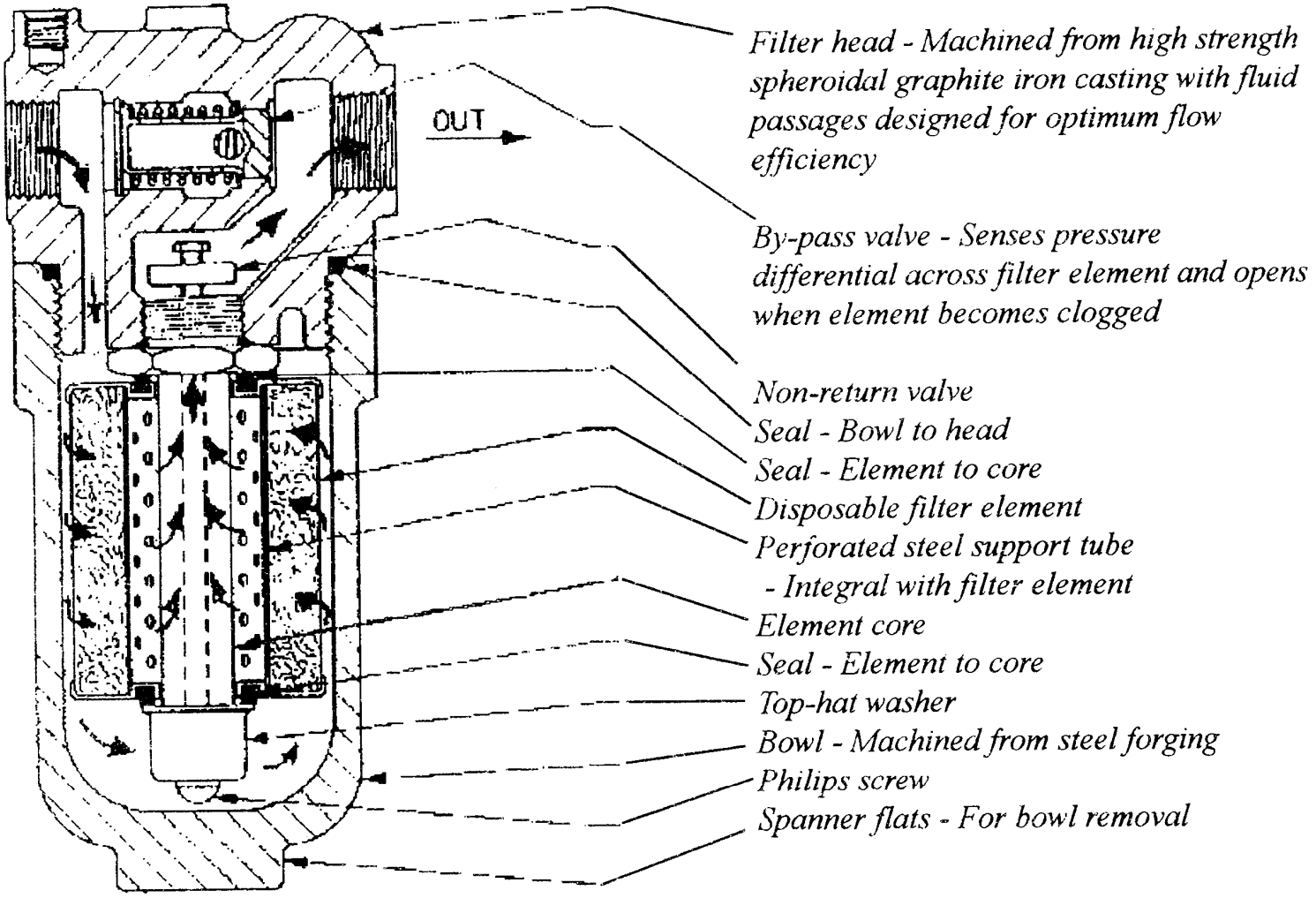
c. A pressure relief valve which is fitted into the feedline immediately after the pump. This sets the volume and pressure that the hydraulic system requires.

d. A strainer which is installed onto the pump suction pipe inside the reservoir. This ensures only clean oil is picked up by the pump.

e. A fine mesh filter which is installed on the feed side of the pump, to ensure the oil being pumped round the hydraulic circuit is clean and free of any contamination.



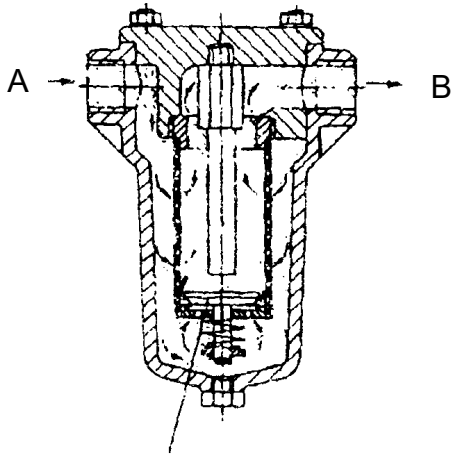
The Oil Filter 1



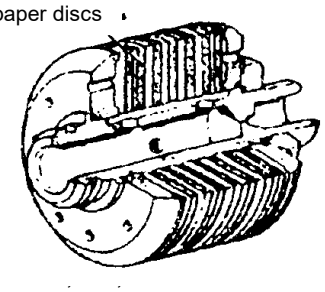
Fitted into the pressure feed line to protect valves and cylinders from contamination which causes wear and deterioration.

Suction-line filtration
The filter is installed in the suction line. It protects the pump against damage caused by foreign matter.
Possibility of damage as the result of cavitation (cf. Exercise on hydraulic motors) in the even of blocked filters.

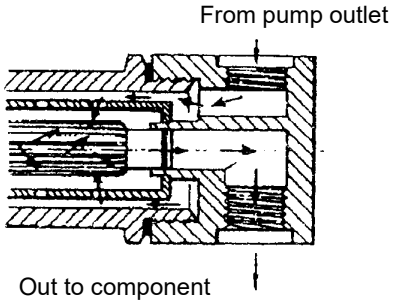
Valve open if filter is blocked. This allows full flow to pump so as not to damage it in the event of filter blockage.
* Blocked filter elements must be changed immediately.



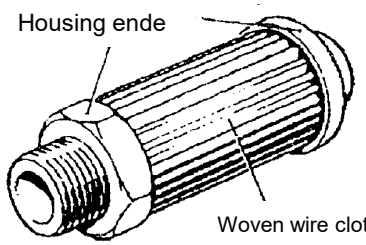
The Oil Filter 2



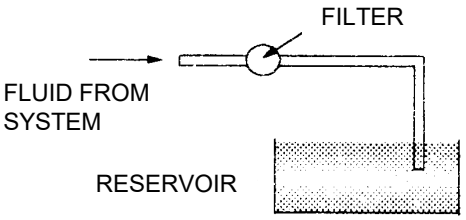
A filter consists of an element which is l ement may be made from a variety of materials such as pape sintered metal.

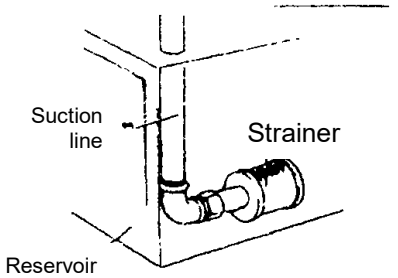


Normally, a filter is fitted in the outlet line from the pump to prevent any contamination caused by the pump from reaching the components.

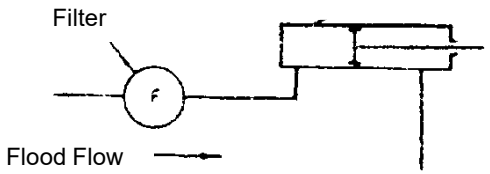


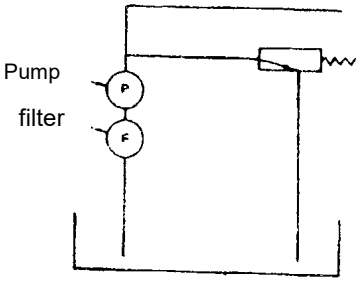
An alternative to this, which is sometimes used, is to fit the filter in the return line to the tank or reservoir.





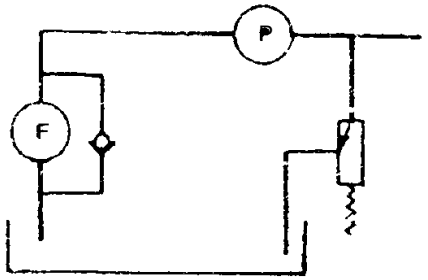
A hydraulic tank normally contains two or three strainer elements. One incorporated in the filler orifice, one in the air breather if this is separate from the filling point and one connected to the suction line to the pump. These strainers are of the fine mesh wire screen type and should be checked regularly for damage. Damage strainers should be replaced immediately. Strainers should also be removed for cleaning at the recommended intervals as laid down in the appropriate schedule.





When servicing an unfamiliar system always check the drawings to ensure that the positions of all filters are known. These can vary from system to system depending on particular requirements.

It may be necessary to protect particularly vulnerable components by the use of additional filters fitted just upstream of the component.

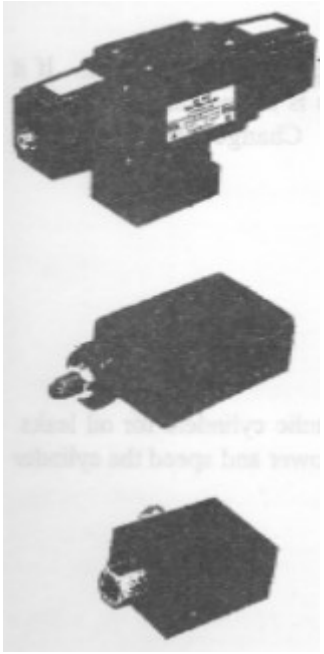


In many cases filters are equipped with bypass valves which open when the pressure drop across the filter become blocked. At the recommended intervals, filters should be removed from the system. Paper disc and felt elements must be renewed. Woven wire cloth elements may be cleaned in a suitable solvent and inspected for damage. A new element must be fitted if the old one is found to be damaged.

Control Valves

Valves are normally mounted onto a manifold on top of the oil reservoir. They are mounted in packs. Each pack of valves is for an individual sequence of the operation.

The valves are pre-set for the correct pressures and flows that the operation requires. These setting must not be interfered with.



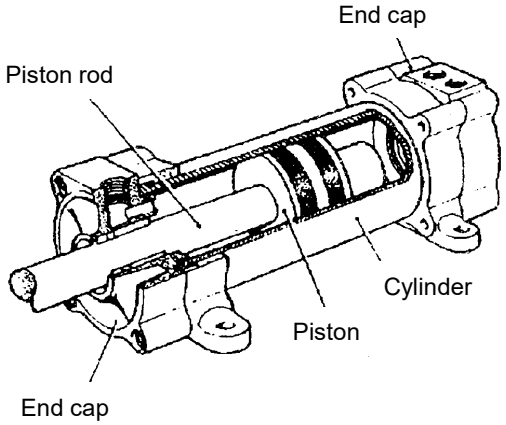
Direction control valve.
Controls direction taken by the fluid by shutting off or opening the passage.

Pressure relief valve.
Limits the working pressure to a specific adjustable valve. Protects the system from excessive pressures. Check valve.

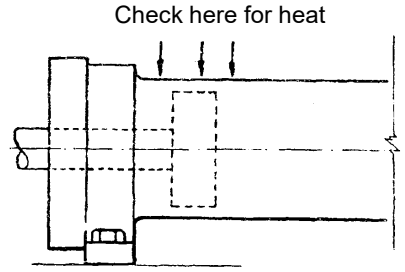
Permits free flow in one direction. Flow is blocked in the other direction until pilot pressure is applied. This prevents loss of pressure if pump line is broken or valve is inadvertently shifted.

Hydraulic Cylinders

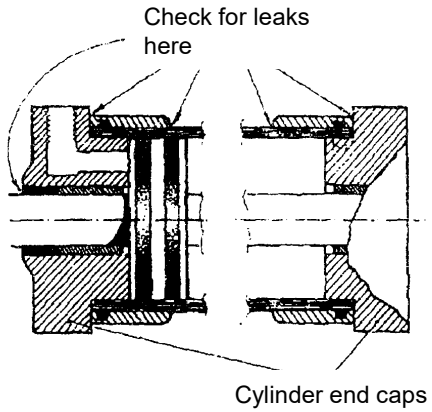
The hydraulic cylinder is the actuator of the hydraulic system, converting hydraulic power into linear motion which is then applied to the machine part that has to be moved.



The cylinder assembly consists of the cylinder which is enclosed at each end by end caps, and a piston and piston assembly. The free end of the piston rod slides in one of the end caps and this is connected to the component to be moved.



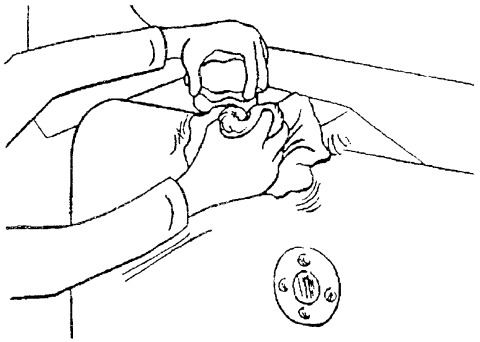
Feel the cylinder wall over the piston position. If it becomes warm or hot this is an indication of leaking piston packing or seals. Change any packings or seals as necessary.



Regularly check the hydraulic cylinders for oil leaks. Oil leaks can reduce the power and speed the cylinder should operate at.

Keeping the Hydraulic System clean.

Be careful when you add oil. always ensure that the top of the reservoir is spotlessly clean. Oil attracts dust and grit, this could find its way into the reservoir if not cleaned regularly.



Keep the oil clean always replace lids firmly onto oil containers

Loss of Fluid due to small leaks.

	1 MINUTE	I HOUR	I DAY	I WEEK	I MONTH
ONE DROP PER SEC	1/10 OZ	8 OZ	1.1 GALL	8 GALL	34 GALL
2 DROPS PER SEC	1/3 OZ	1 PINT	2 2/3 GALL	26 GALL	2 BARRELS
DROP BREAKING INTO STREAM	2 OZ	1 GALL	24 GALL	3.5 BARRELS	14 BARRELS
1/16 DIAMETER STREAM	7.5 OZ	3.5 GALLS	84 GALL	11.5 BARRELS	50 BARRELS
1/8 DIAMETER STREAM	23 OZ	11 GALLS	266 GALLS	36 BARRELS	158 BARRELS

All leaks should be stopped immediately. They can also allow air and dirt into the system when the machine is turned off.

Temperature problems

Part of any inspection check on a hydraulic system must be a temperature check.

An overheated hydraulic system is a sure indication that something is wrong and must be checked out immediately.

Main problems of overheating are a blocked filter or low level of oil in the reservoir.

Report any temperature problems immediately to the maintenance department.

Low temperatures:

Principle danger is that oil may become too thick to be drawn through the suction line and the pump may be starved.

Lack of oil, even for short periods, may cause excessive pump wear if not actual seizure.

High temperatures:

Excessively high oil temperatures have the following effects:

Firstly, due to the oil being thinner, its function as a lubricant is reduced and wear may be increased.

Secondly, the rate of deterioration of the oil and formation of contaminants is increased.

Thirdly, due again to oil being thin, internal leakage in pumps and valves is increased and the efficiency of the hydraulic system is reduced.

The following table gives a guide to working temperatures of oil: -

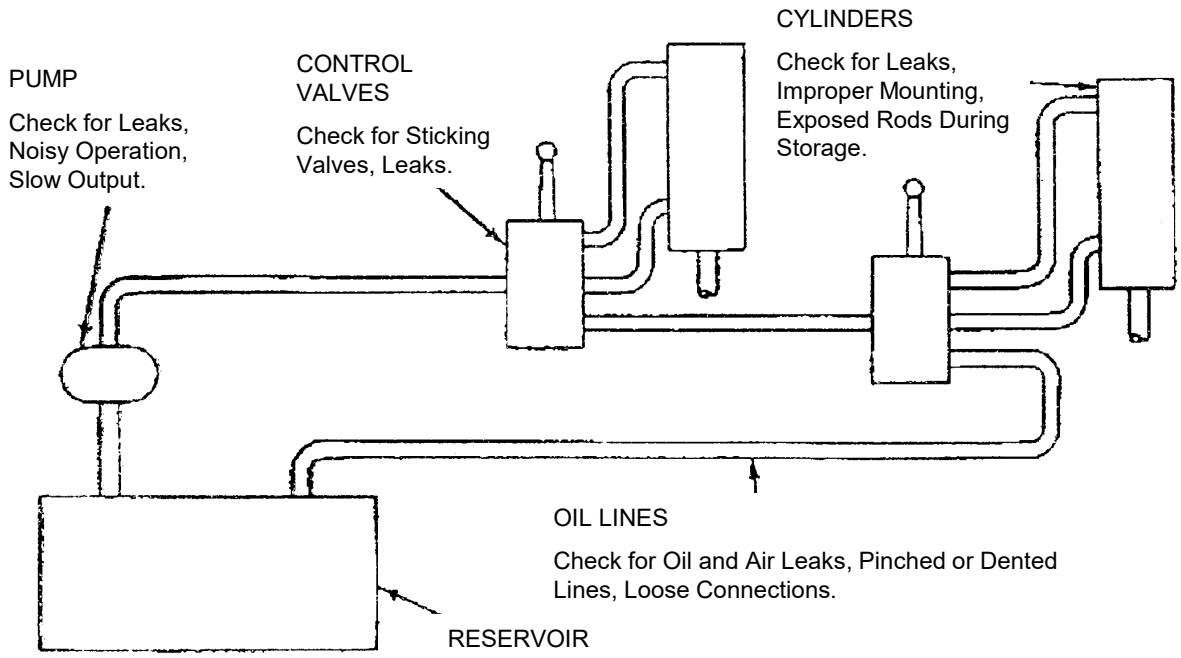
Temperature in ° F	**Working Conditions**
up to 115 (45℃)	**Ideal Working Conditions**
115-130 (45-55℃)	**Still in safe range**
130-150 (55-65℃)	**Shortened oil life expected**

All systems should be designed to operate at a maximum temperature of 40 (105F). At this temperature the oil life can be expected to exceed 10,000 hours providing that no contamination occurs.

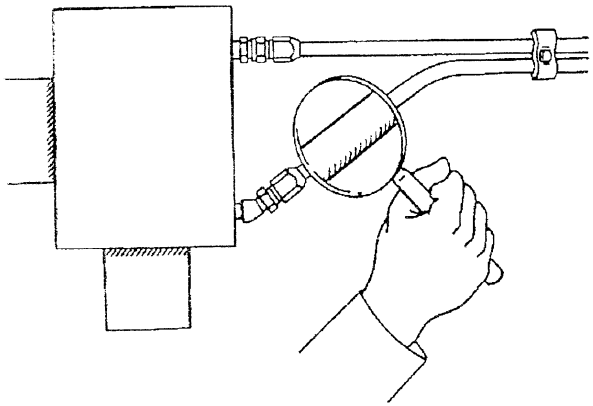
As a general guide, where the input of the circuit exceeds the power output of the actuators by more than 2 h.p. (1½ k.w.) an oil cooler is likely to be required.

Also, consideration should be given to the size of reservoir for dissipating heat.

Checks to make on Hydraulic Systems

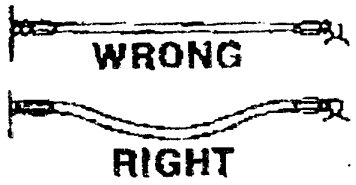


Checking for oil leaks

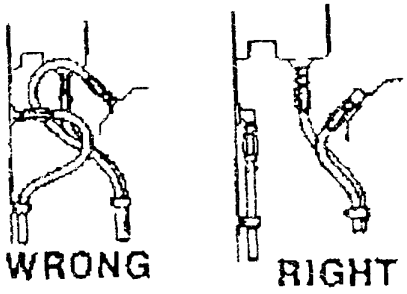


A small leak will soon drop the level of oil in the reservoir. Low oil level causes problems.

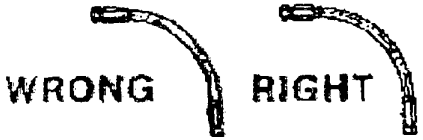
Are Hoses fitted correctly



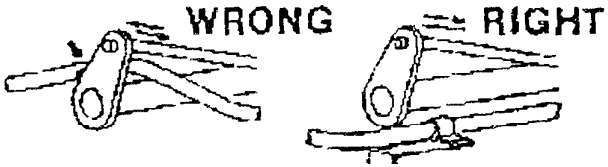
1. AVOID TAUT HOSE



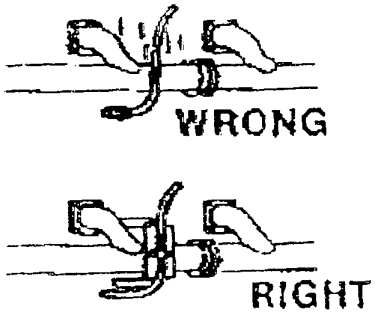
2. AVOID LOOPS



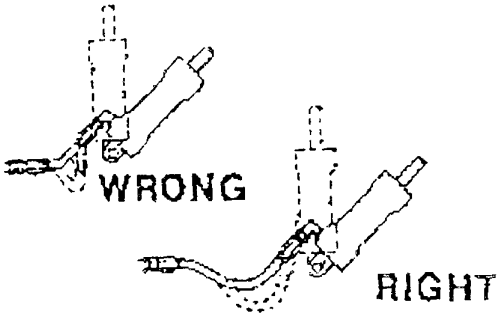
3. AVOID TWISTING



4. AVOID RUBBING

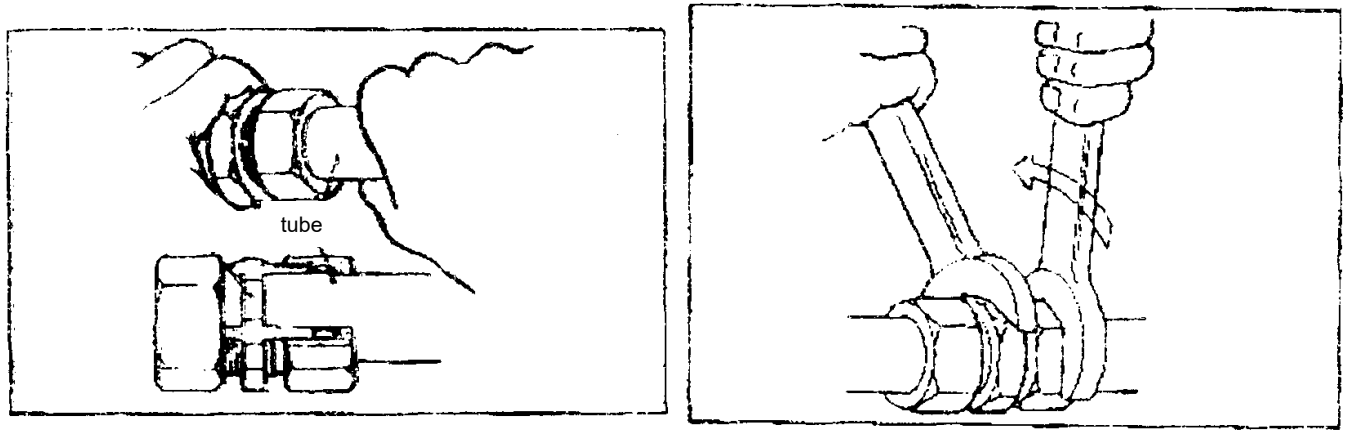


5. AVOID HEAT

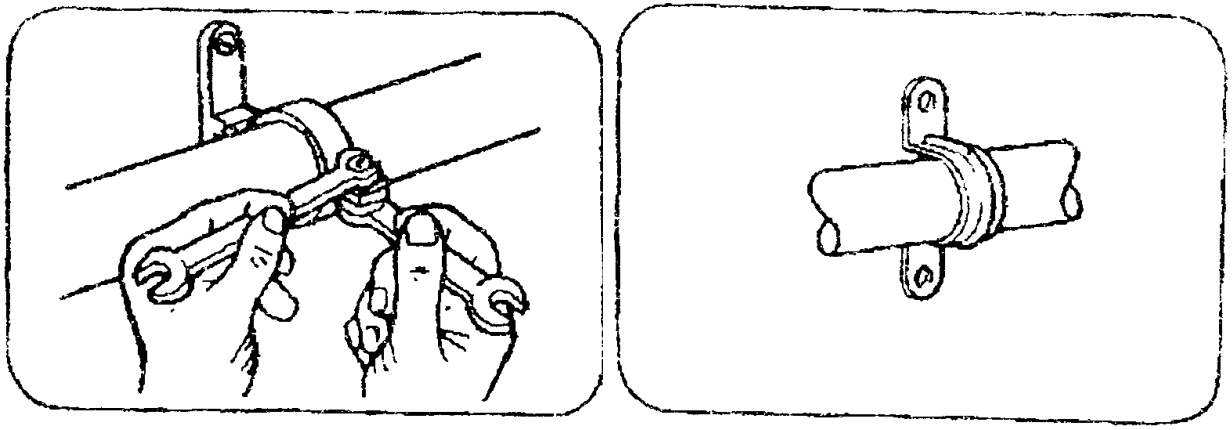


6. AVOID SHARP BENDS

Check all hydraulic pipe couplings are free of leakage. All couplings must be tightened securely.

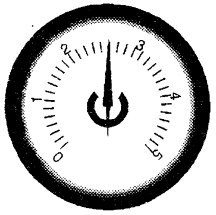


Ensure all pipework is properly secured to reduce vibration.



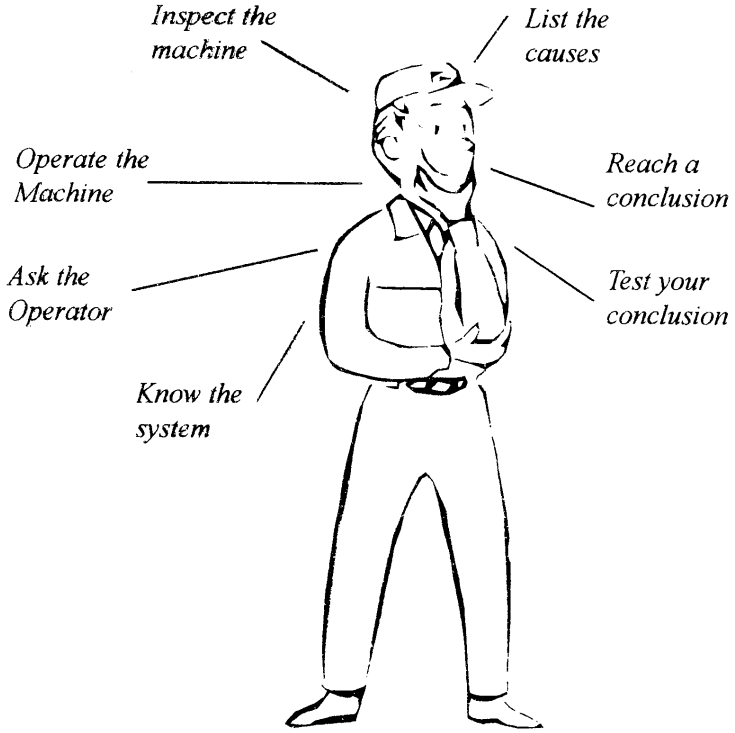
Pressure Gauges

Ensure all gauges are reading correctly and are set at the pressure the system requires if reading incorrectly, report to the maintenance department.



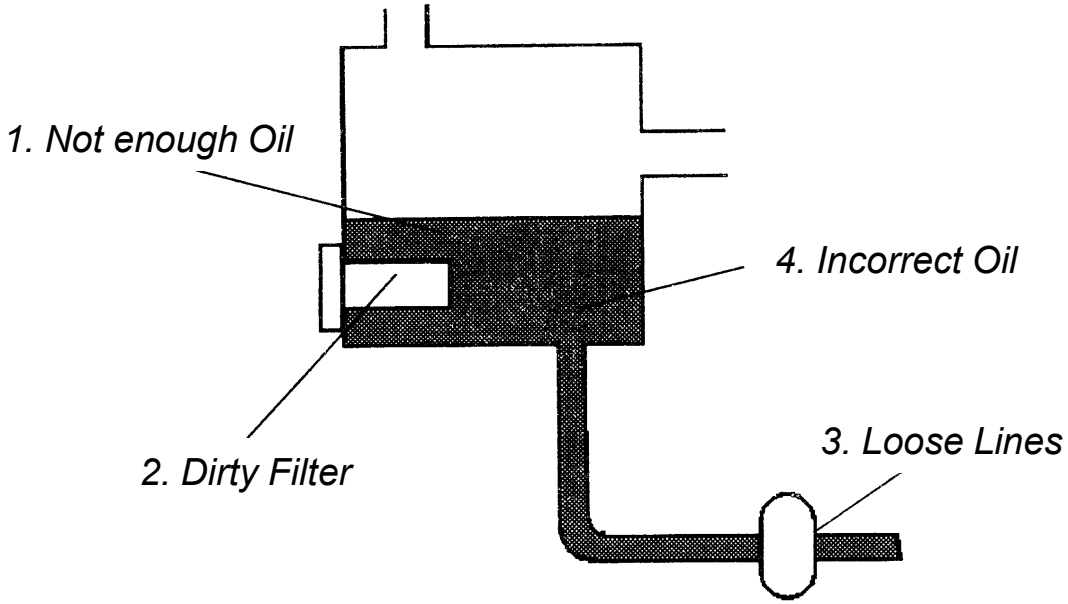
Hydraulic gauges are quite often tilled with glycerine to protect them from vibration and sudden high pressures.

Diagnosis and Testing of the System

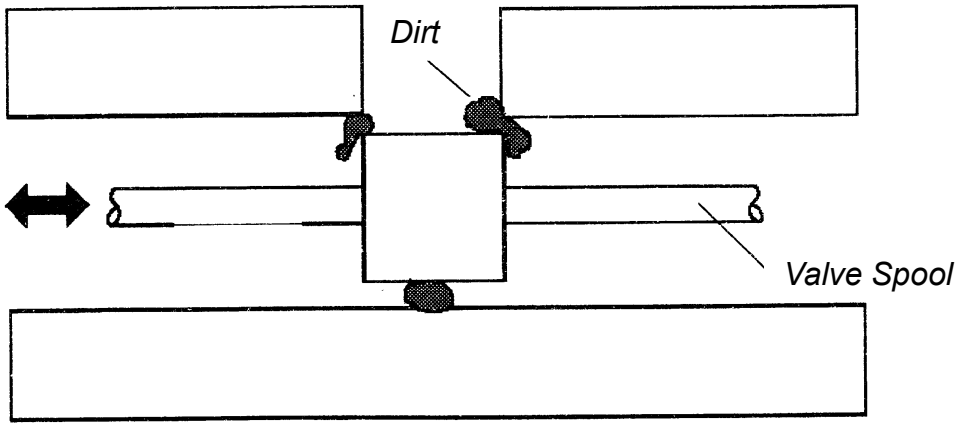


Mr Trouble Shooter

Major Maintenance Problems



Dirty Fluid will wear Valves



Points to consider when making up an inspection schedule for a hydraulic system.

a. Pressure gauges installed in the system record the pressure the system is working at. The operating pressure should be marked by a red circle with a gap on the gauge dial face. The pointer needle of the gauge should always show in the gap when the system is operational.

b. Filter units are normally provided with blockage indicators. When on green they are clear, but when on red they are becoming blocked and require renewing.

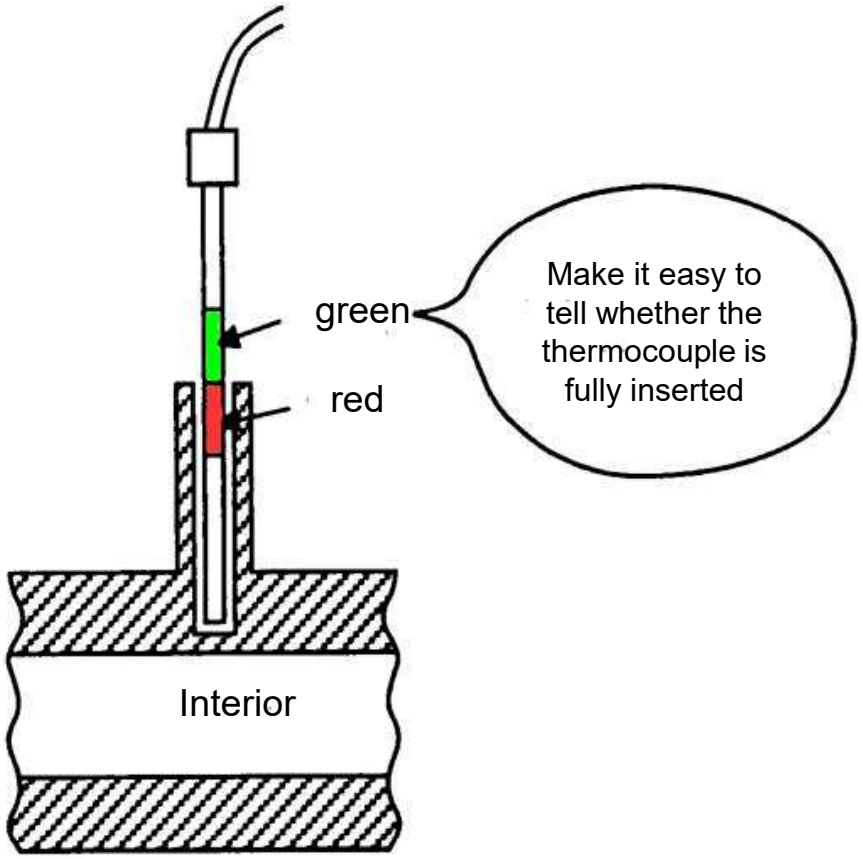
c. Oil leaks, even small ones, will soon drop the level of oil in the system. This will affect the operation and performance of the system. They should be rectified as they occur.

d. Components should be regularly checked for overheating. This is an indication that something is wrong and requires immediate investigation.

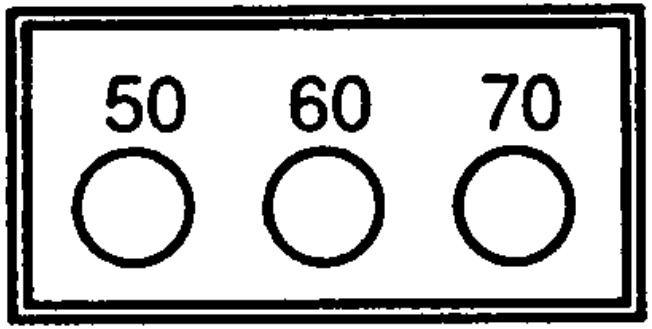
e. Damaged components and pipework will eventually lead to them breaking down. They should be renewed.

f. Oil levels in the hydraulic system should be maintained at all times. Low oil levels lead to overheating and malfunction of the system.

g. Always ensure the system is clean and free from contamination by regular cleaning. Contaminated oil will cause wear to components in the system.


green
red
Make it easy to tell whether the thermocouple is fully inserted
Interior

Figure

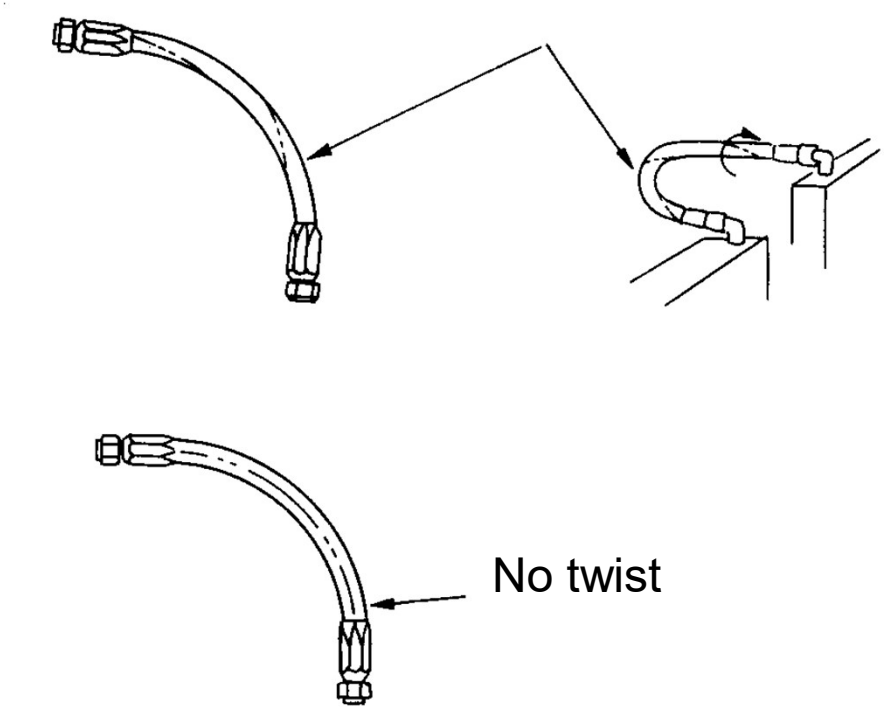


Install in pumps, valves,
bearings, motors, etc.

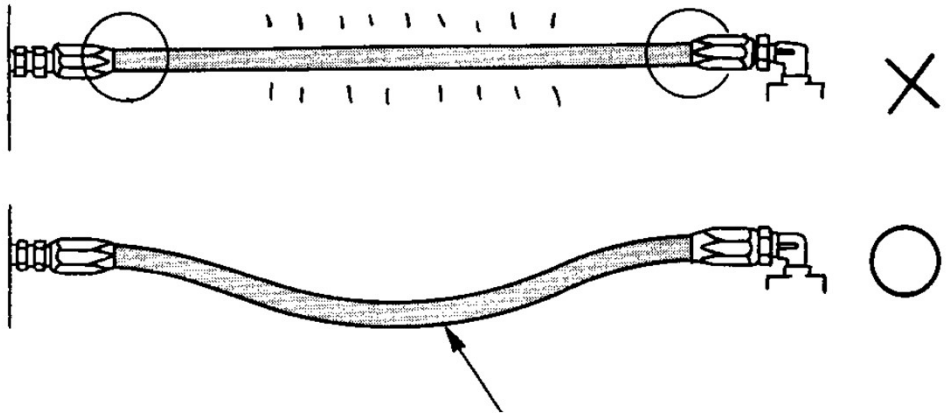
Insertion of thermocouples

Do not twist hoses !

When there is twist, a puncture takes place.

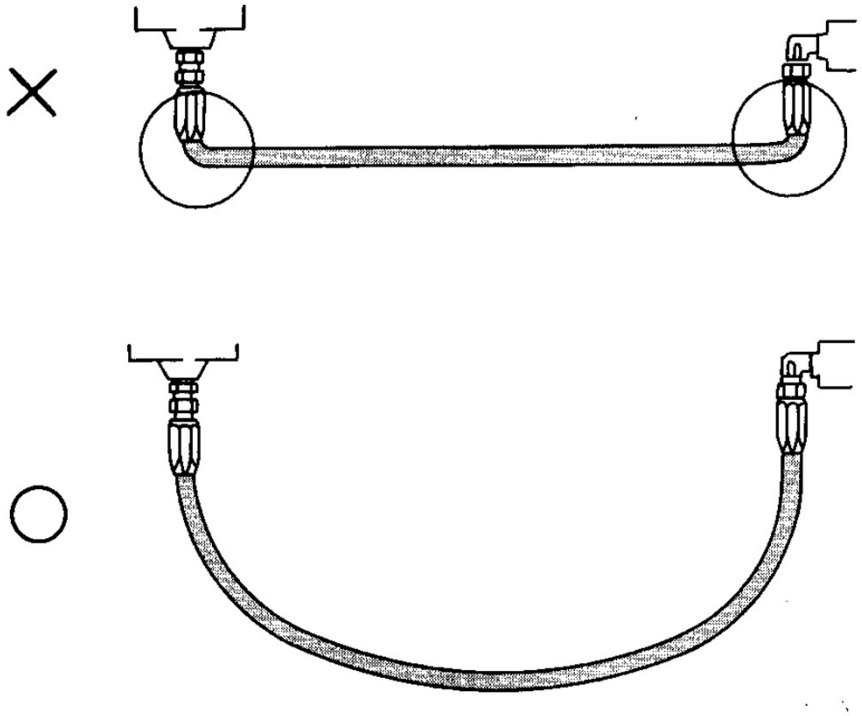


Do not use hoses in a stretched state!

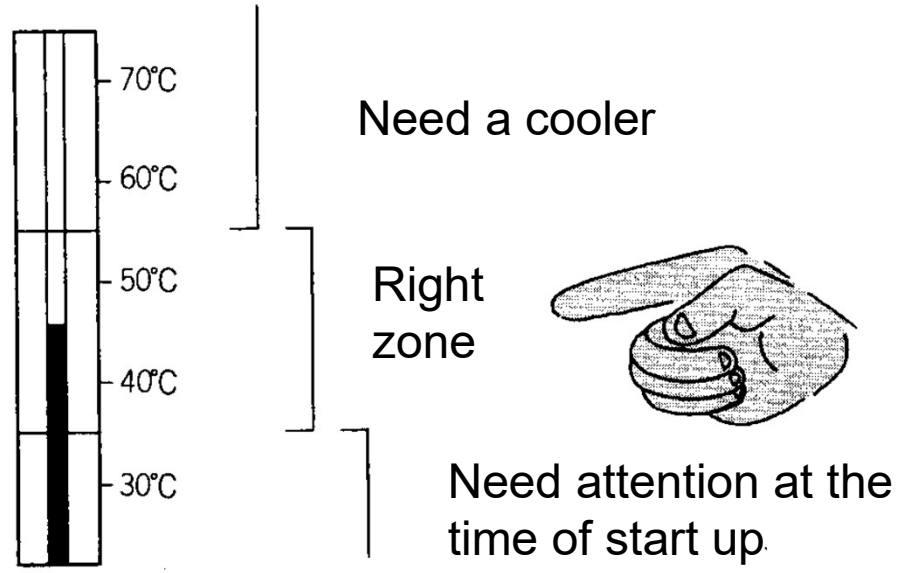


Flexible

Do not bend hydraulic hoses too much!



Do not bring oil temperature above 60 degrees in the hydraulic tank !

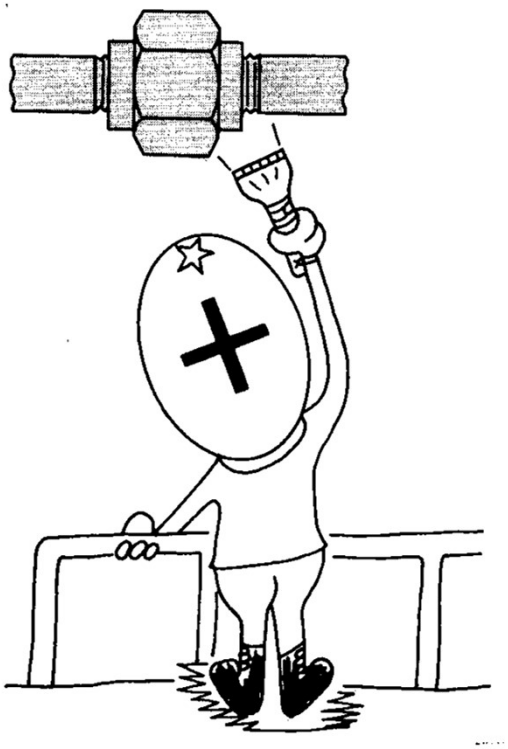


Inspection Checklist - Malfunctioning Oil Pressure Pump

Check Items	Inspection Results		Check Items	Inspection Results	
1. Discharge pressure set correctly?	standard: 20±2 kg/cm^2 actual: 20.5 kg/cm^2	OK	5. Coupling normal?	Yes	OK
2. Normal amount of oil in tank?	Within level range	OK	6. Pump and motor axes cantered?	standard ≤ 1mm off center actual: .08mm off center	OK
3. Strainer free of debris?	very clogged	✔	7. Noise, overheating, or vibration in pump?	a lot of noise, overheating, and vibration	✔
4. Hydraulic oil clean, no air bubbles?	very dirty, also cloudy	✔	8. Noise, overheating, or vibration in motor?	No	OK

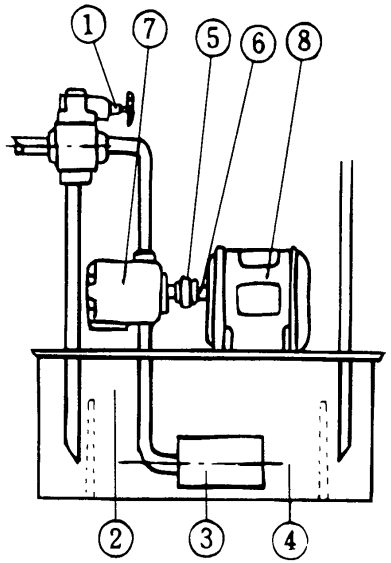
Do not leave small oil leakage !

By finding causes, we will be able to increase the maintenance level.

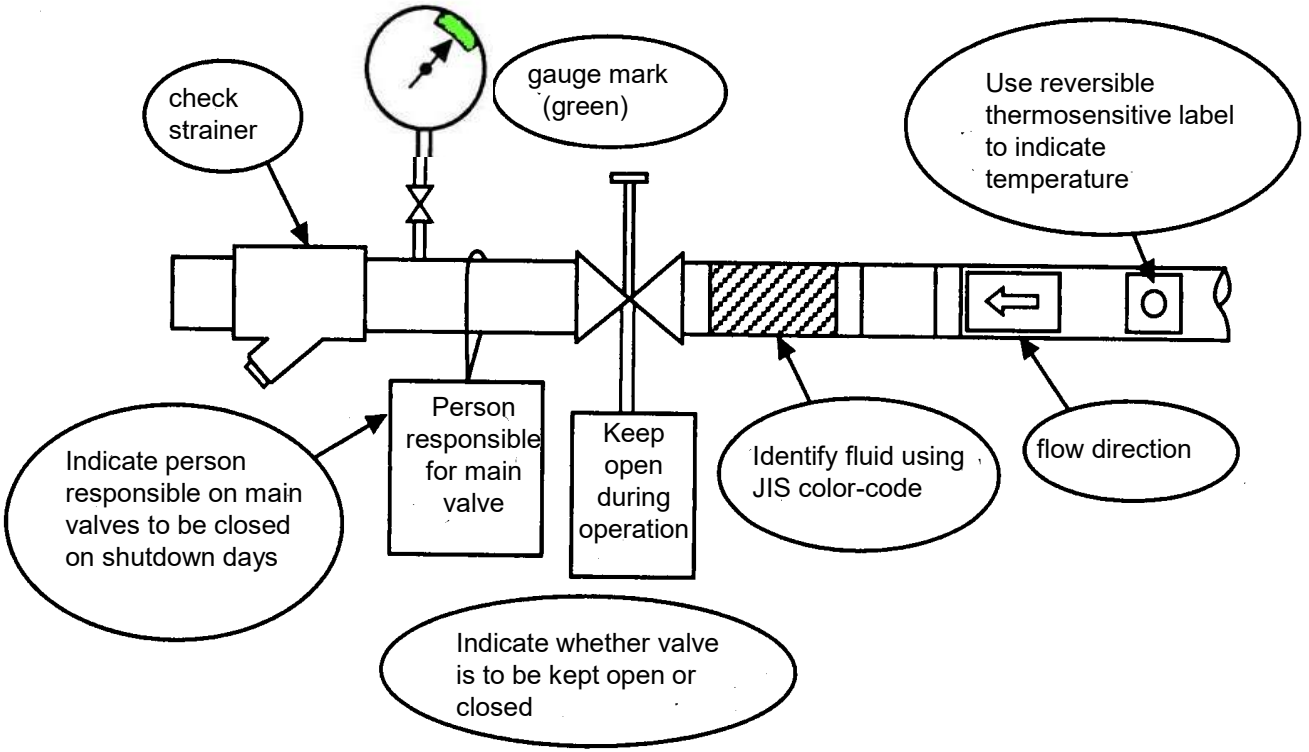


Sample Inspection Checklists

Oil Pressure Pump
Check Items
1. Discharge pressure set correctly
2. Correct amount of oil in tank
3. Strainer not clogged by debris
4. Clean hydraulic oil, no air bubbles
5. Correct coupling
6. Pump and motor axes properly centered
7. No noise, overheating, or vibration in pump
8. No noise, overheating, or vibration in motor



Piping


check strainer
gauge mark (green)
Use reversible thermosensitive label to indicate temperature
Indicate person responsible on main valves to be closed on shutdown days
Person responsible for main valve
Keep open during operation
Identify fluid using JIS color-code
flow direction
Indicate whether valve is to be kept open or closed

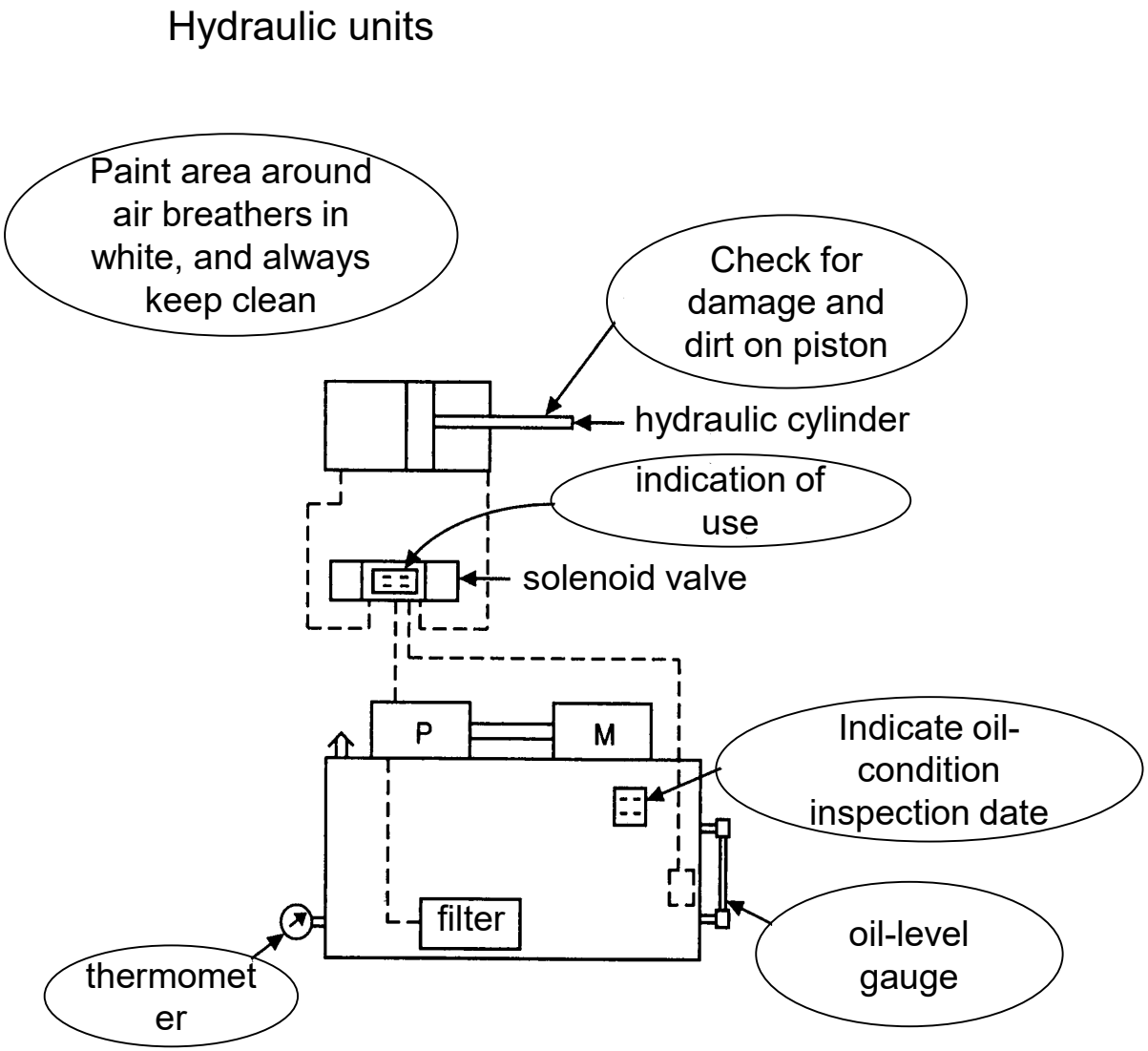


Figure. Example of General Inspection Items

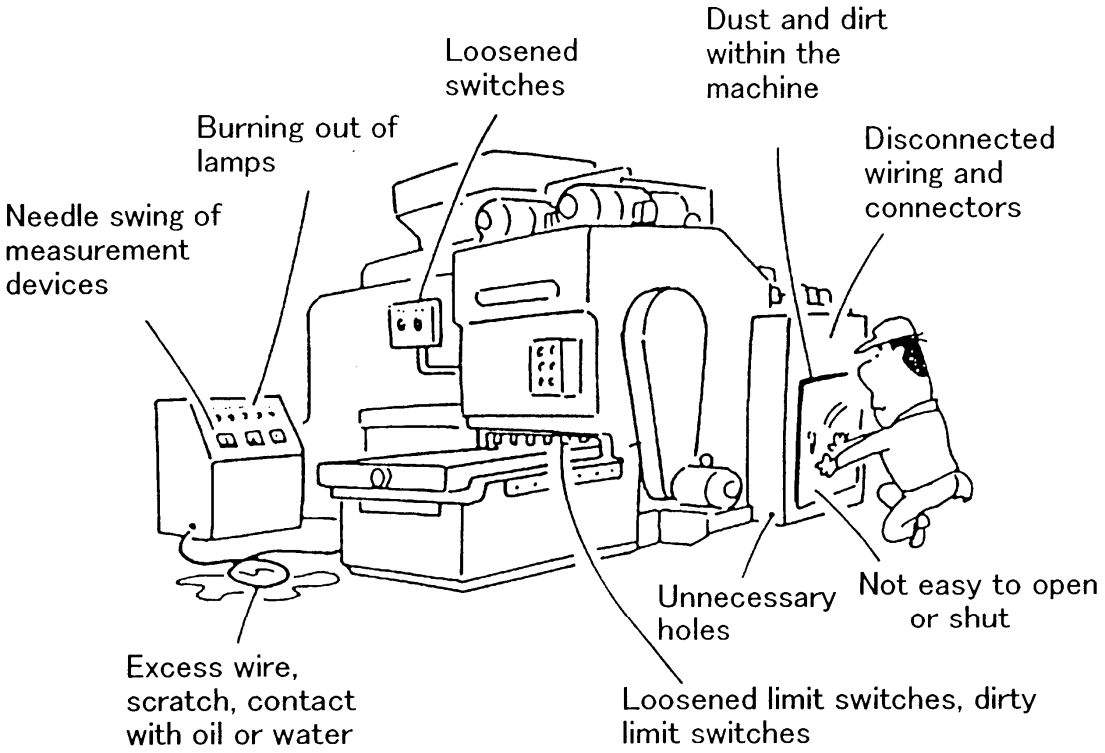
The four main enemies of hydraulic fluid

1. Air entrainment - no frothing.
2. Foreign matter (water, dust, foreign fluids) - clean air breathers, check filters, take care when changing fluid, inspect and clean fluid, etc.
3. High temperature - temperature should be below 55℃. Also be careful about differences in inlet and outlet fluid temperatures in heat exchangers.
4. Leaks - maintain packing and prevent vibration.

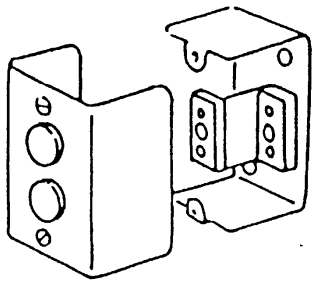
Electrics

Contents

Danger
Electricity supply
What is a transformer?
Motors
Electric Motor
Sensors and controls
Photo electric cells (P.E.C.s)
Check list



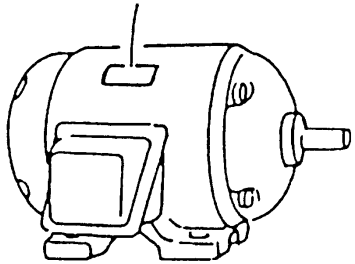
Skill training (e.g.)



Exchanging method of switches

Visual control (e.g.)

Thermo-label



Danger

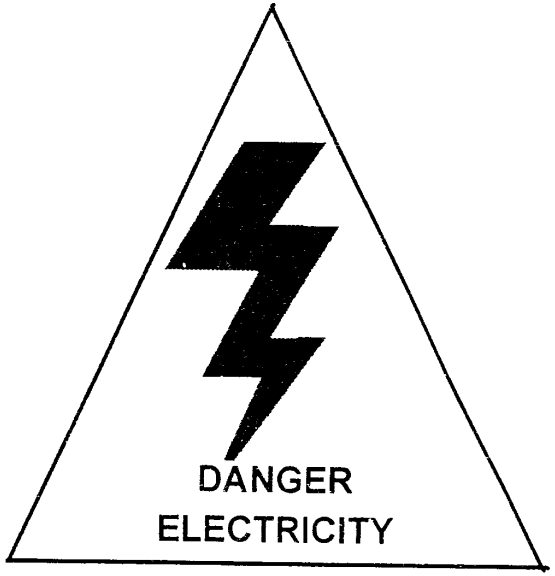
Electricity

Is the only natural phenomenon which cannot be seen, touched, smelled, heard or tasted.
Only the effects of it can be and if you treat it with respect it will serve you well.
The golden rule must always be –

If in doubt ***DON'T!***

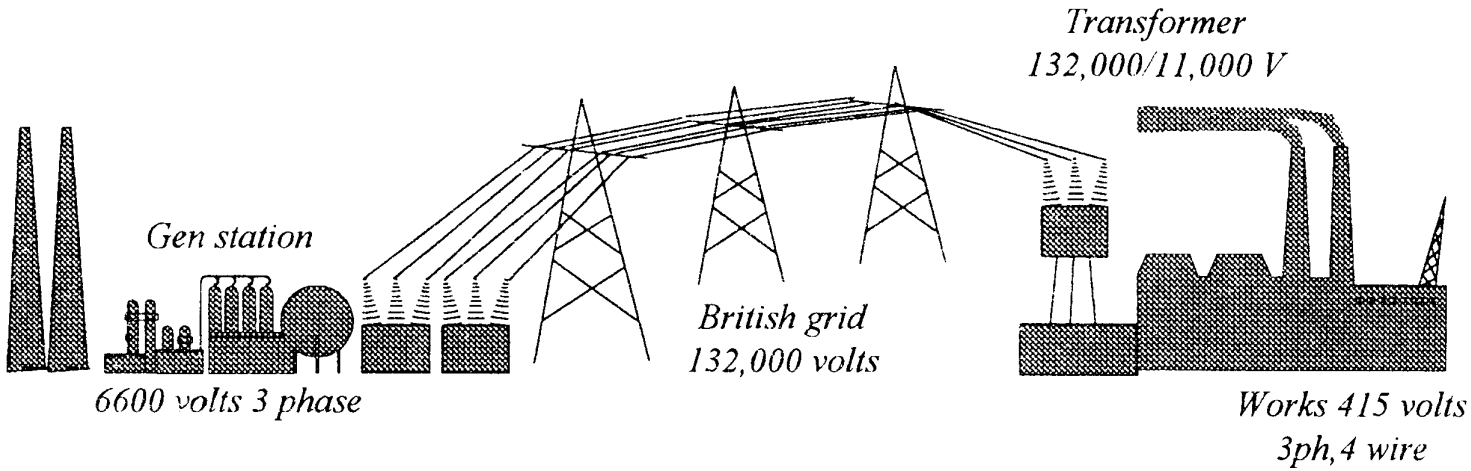
If you are not sure that what you are checking or doing is safe, report it and leave it to the

Maintenance Department.



Electricity supply

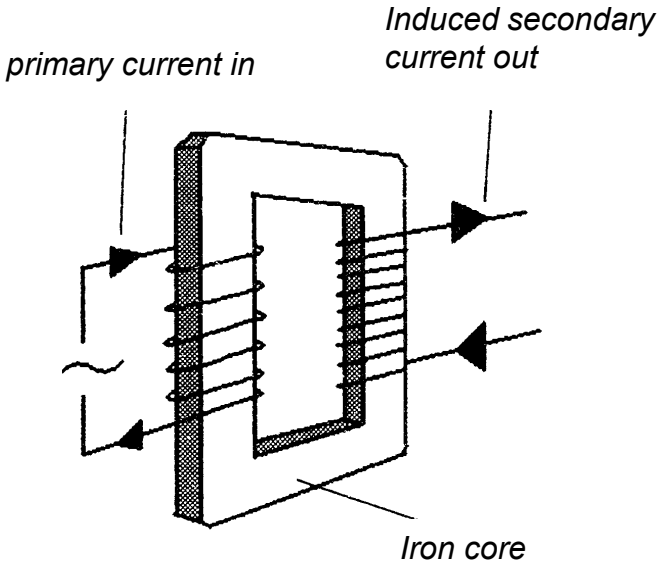
Electricity is supplied to the factory by the generating company's via the distribution network owned by the regional electricity board (in our case NORWEB – the North Western Electricity Board). It is supplied at a voltage of 11000 volts (11Kv) and is stepped down (or transformed) to voltages of 3,300 volts (3.3Kv) and 415v on site for our use. The reason for the high voltage on the supply into the factory is to reduce losses in the national distribution system caused by the distances the electricity has to travel.



The electricity is distributed around the factory from our own substations, which contain the necessary switchgear to safely control the transformers, which step down the voltage and also the main distribution boards in the factory. The 3.3Kv supply is only used on machines which are required to develop high energy at acceptable costs (e.g. Banbury mixers, Mills and Boiler house compressors). In general the supply to most machines in 415v. Some items on machines will require this voltage to operate (motors and drive systems to control motors), but most control systems on machines require a supply of 110v or 24v. These lower voltages are achieved by further small transformers inside the machine panels.

What is a transformer?

If a magnet is moved through a coil or wire, it can produce a current in the wire. This is called electromagnetic induction. Transformers work by electromagnetic induction. They contain a soft iron core which is wrapped with a few turns of wire that form the primary coil. An alternating current flows through this wire. The core is also wrapped with a secondary coil of wire that has a different number of turns. If the secondary coil contains more turns than the primary coil it will have a greater output voltage than that of the primary input. The current in the secondary coil is induced by the alternating current in the primary coil. The ratio of input to output voltages is roughly equal to the ratio of the number of turns of wire in the primary and secondary coils. A transformer that changes current at one voltage to current at a higher voltage down is called a stepdown transformer. Step-down transformers are used to reduce the voltage of 400,000 volts, at which the mains supply is transmitted across the country to the voltage at which it is used in our homes, about 240 volts.



Motors.

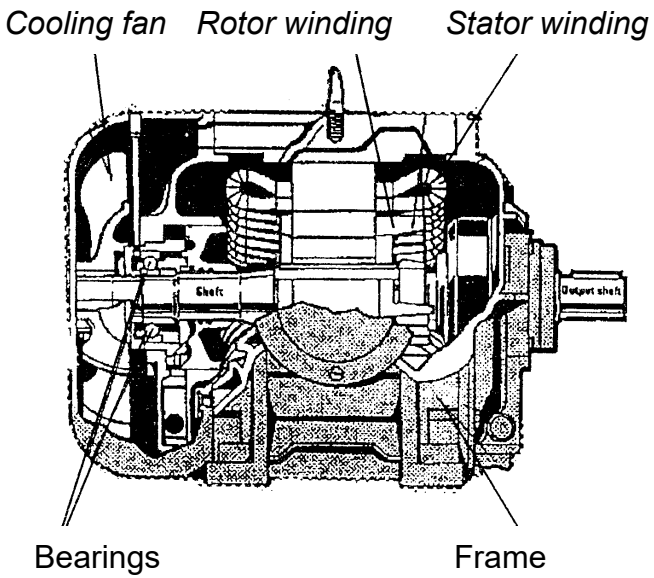
The driving force of most machines is an electric motor, these come in two forms – alternating current (AC.) or direct current (DC.). Your machine may have either of these and probably both. As a rule AC. Motors operate at a fixed speed and DC. Motors are used where variable speed required. The latest trend with smaller AC. Motors is to also vary their speed where required by means of a special type of electronic drive known as an “invertor drive” and these are beginning to

be used on some machines. The main way to determine whether a motor is AC. or DC. Is whether it has carbon brushes fitted. Some very small AC. Motors have brushes fitted, but as a general rule if brushes are fitted the motors is a DC one. You can help maintain the motors on your machine by:

1. Report any unusual noise or vibration.
2. Check for overheating, either by smell or touch.
3. Reporting any sparking at the brushes on DC. motors (these are either visible or under a vented cover at the end of the motor furthest from the driver shaft).

Electric Motor

How does an electric motor work? The principle of the electric generator is based on the fact that, if a conductor is moved through a magnetic field, a current is induced in the conductor. The electric motor works on the converse principle. If a current is passed through a conductor which is situated in a magnetic field, the conductor will be made to move. In a simple motor, the conductor is a coil, the armature, which rotates between the poles of a magnet. This produces a direct rotational movement to the drive shaft. Current is supplied to the coil through a commutator, which reverses the direction of the current. In this way the shaft is kept turning in the same direction. Some motors run on direct current (DC) others run on alternating current (AC).

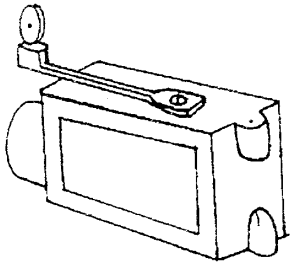


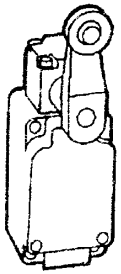
Sensors and controls

There are numerous ways of sensing what is happening on a machine and controlling its operation. Some of the most common ones are: -

1. Limit switches
2. Proximity switches.
3. Proto electric cells (P.E.C.s). There are certain to be some of these on your machine and probably all of them. Sensors work at various voltages, usually either 110v or 24v and probably all of them. Sensors work at various voltages, usually either 110v or 24v and the type and variations are so numerous it would be impossible to illustrate them all, but here are a few typical examples.

Limit Switches





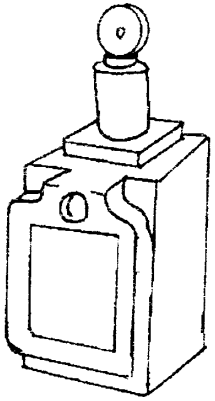


Photo electric cells (P.E.C.s).

These control devices are the source of probably more breakdowns than any other electrical equipment on your machine – due to being either slack, dirty or damaged. You can help maintain the control devices by ensuring that switches are secure and undamaged and that P.E.C.s are clean, secure and lined up with their reflectors.

Protective devices

There are several types of devices used to protect the electrical equipment on your machine.

1. Fuses
2. Circuit Breakers
3. Overloads

These are usually enclosed in panels accessible only to maintenance personnel, but your machine may have built into indicators to tell you when a protective device has operated. There may be indicator lamps identified as “Power”, “Tension”, “Supply On”, etc. If your machine will not switch on and these lamps are not lit, it may be that a fuse has failed or circuit breaker trapped. Some machines have indicator lamps to indicate when an overload has tripped and will be identified as such. Although you may not have access to the protective devices themselves, there may be symptoms on your machine as to why a device has operated: -

1. Is anything obviously tight or making an unusual noise?
2. Is there anything jamming or obstructing part of the machine?
3. Is there a burning smell? (The usual causes of burning on a machine are faulty transformers or motors).

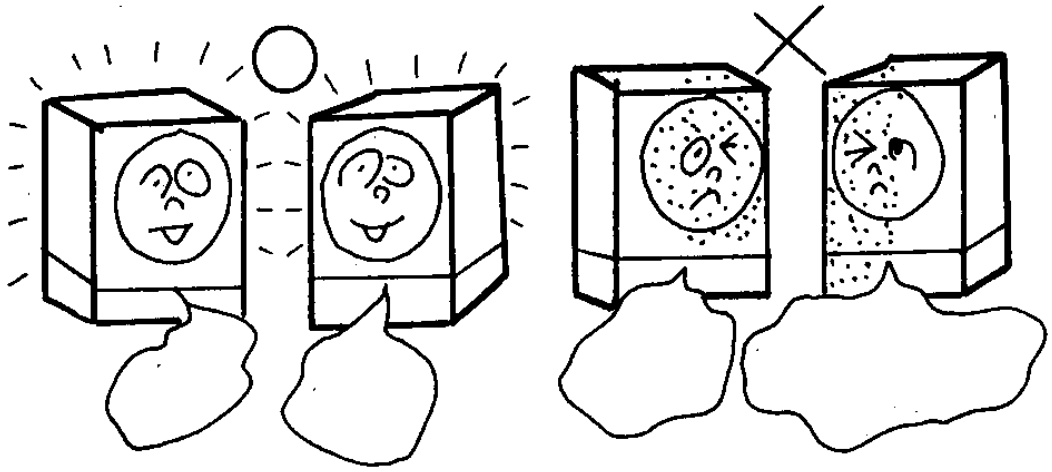
If you detect any of these symptoms, switch off your machine immediately at the main insulator and have it investigated. You will not damage anything and you may prevent a costly breakdown.

WHERE	WHAT	CHECK FOR
Drawing or machine plan	Cabinet doors and panels	Check they are secure and undamaged.
Drawing or machine plan	Water oil Air	Leaks onto or from panels
Drawing or machine plan	Stop buttons Kick bars Pull wires	Are free from obstructions and operate correctly
Drawing or machine plan	Indicator lamps	Are secure, working and have lamp covers fitted
Drawing or machine plan	wiring	Wires exposed or damaged
Drawing or machine plan	Trunking and conducts	Damaged or missing covers
Drawing or machine plan	All sensors	Are clean and secure
Drawing or machine plan	Motors	Signs of overheating or vibration
Drawing or machine plan	Wire protection	Check if measures are in place to prevent damage to wiring etc

Point of cleaning

(Lenses of a photo cell)

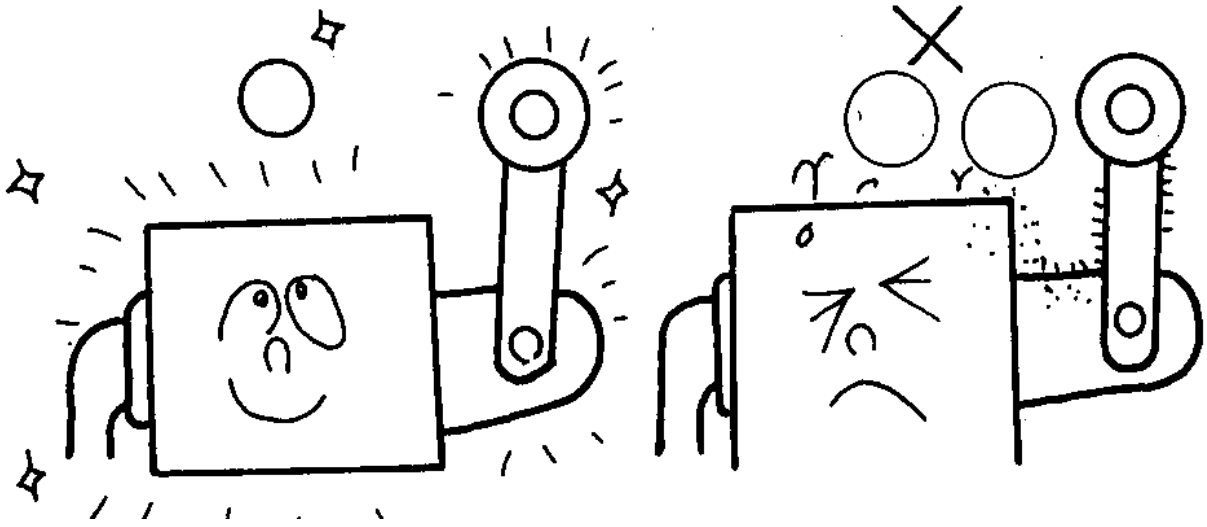
Clean with a soft cloth..



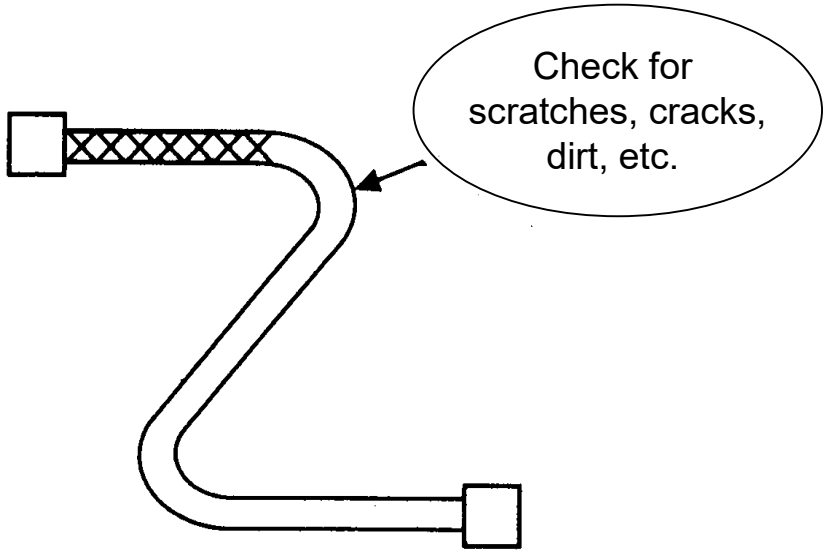
Point of cleaning

(Limit switches)

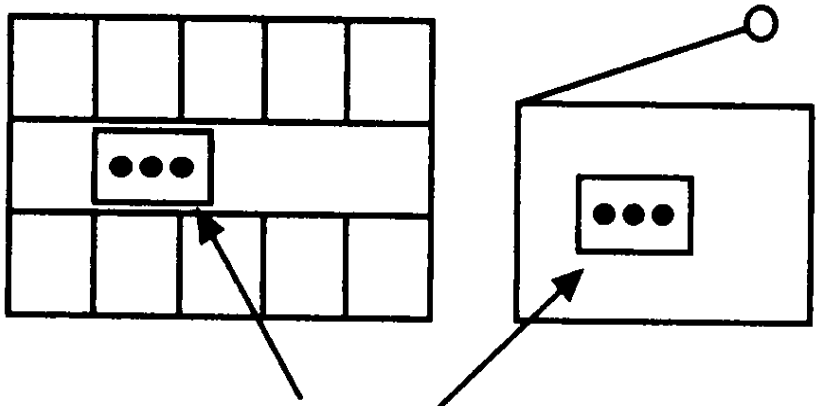
Remove attached dust and dirt.



Surface damage to high-pressure hoses and wiring.



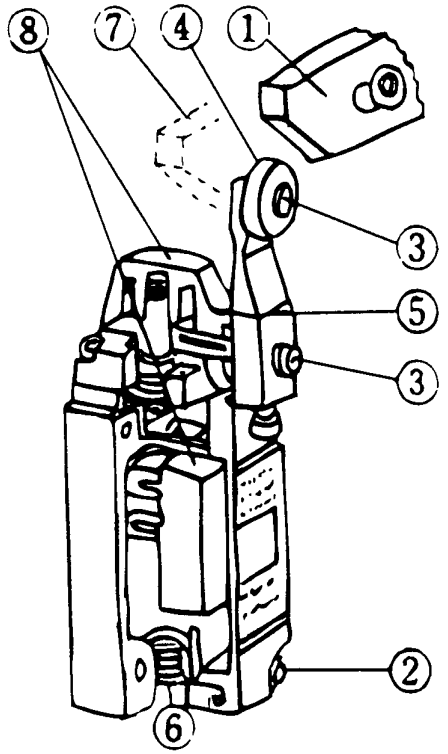
Display of replacement date on electrical parts (limit switches, relays, etc.)



Label showing replacement date

Sample Inspection Checklists

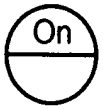
Limit Switch
Check Items
1. Correct stop position
2. Correct limit switch position
3. No play in pin
4. Roller on track, no slippage
5. No debris obstructing moving parts
6. Voltage and current within rated values
7. Lever motion within limit values
8. No liquid or vapor on switch



Inspection Checklist – Limit Switch Breakdown

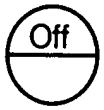
Check Items	Inspection Results		Check Items	Inspection Results	
1. Correct stop position	Position normal	OK	5. No debris on moving parts	None	OK
2. Correct limit switch position	Position normal	OK	6. Voltage and current within rated values	Rated: AC 200 V 2A Actual: 198 V 1.2A	OK
3. No play in pin	No play	OK	7. Lever motion within limit values	Standard: within 90° Actual: within 60°	OK
4. Roller on track, no slippage	On track	OK	8. No liquid or vapor on switch	Some coolant on switch, but it's waterproof	✔

Display of easily mistaken pressing sequence for buttons



Indicate sequence in black

Application: to display starting sequence
To indicate order in which switches, buttons, etc. are to be operated when starting equipment



Indicate sequence in red

Application: to display sequence for stopping equipment
To indicate order in which switches, buttons, etc. are to be operated when turning equipment off

Application: inspection date sticker
Record scheduled inspection date and affix to part to be inspected

Appendix : Knowledge Assessment

This knowledge assessment is directed to the following skills :

* Safety
* Lubrication
* Bearings
* Chain drives
* Belt drives
* Hydraulics
* Couplings

Knowledge Assessment

This assessment is multiple choice. Select the best answer.

Knowledge area ： Safety

1 What term is used to describe places where moving parts meet or come near each other?

A. Guard
B. Closer
C. Pinch points
D. Assembly point

2 What is another name for back-and-forth motion?

A. Reciprocating motion
B. Away
C. Advancing lateral
D. None of the above

3 What is the term “point of operation”?

A. The section of the process where the machine centers meet

B. The main focus of process

C. The place where the raw material or work-piece is processed by a machine

D. A point where operators cannot see

4 If a bench grinder is equipped with safety guards, is it necessary for you to wear personal protective equipment?

A. Yes

B. No

5 What type of machine guard limits the operator’s access to the danger zone?

A. Safety chain

B. E-stop

C. A barrier guard

D. None of the above

6 What type of machine guard prevents access to the danger zone altogether?

A. An enclosure guard

B. Safety chain

C. Barrier guard

D. None of the above

7 What kind of guards cannot be moved when a machine is in operation?

A. Barrier guards

B. Fixed guards

C. E-stop guards

D. None of the above

8 What type of guard prevents a machine from operating when the guard is opened or removed?

A. Barrier guard

B. Tape less guard

C. An interlocking guard

D. None of the above

9 What type machine guard is capable of physically pulling an operator's hands out of the danger zone?

A. An automatic guard

B. Barrier guard

C. Restrictive guard

D. None of the above

10 When will a presence-sensing guard stop a machine?

A. When a person is located outside of the danger zone

B. When a light signals a safety alert

C. There is no such item

D. When a person or object enters the danger zone

11 What kind of controls does a machine have if the operator must remove both hands from the danger zone in order to start the machine?

A. Hand-free controls

B. Two-hand trip controls

C. Standard controls

D. Automatic controls

12 What kinds of tools make it unnecessary for an operator to reach into the danger zone?

A. Hand-extraction tools

B. Local guarding tools

C. Feeding and extracting tools

D. None of the above

13 Under what conditions would you remove someone else's lock from a lockout device?

A. When plant manager or maintenance manager approves

B. When the person that installed the lockout cannot found after 30 minutes

C. When you think the it is OK to do so safely

D. According to your plant's lockout procedure

14 What must your employer provide in addition to the appropriate PPE?

A. Training in its use

B. Safety bulletins

C. Training material and trainers

D. None of the above

15 What is your responsibility before using PPE?

A. None

B. You must inspect it

C. Locate all documents controlling it

D. You must report its condition to your supervisor

16 Why should you avoid loose-fitting clothing in the plant?

A. It can create a barrier from sharp parts

B. It can get caught in moving parts

C. It is unprofessional

D. None of the above

17 What should you do if you accidentally come in contact with a dangerous chemical?

A. It depends on the chemical

B. Report to the safety director

C. Shower for at least 15 minutes to rinse thoroughly

D. None of the above

18 How much clearance should hard-hat webbing provide between your head and the top of the shell?

A. Close as possible

B. 1/2”

C. Does not matter

D. 1”

19 How can you keep dust and liquids from reaching your eyes from any direction?

A. By wearing safety goggles

B. By wearing safety glasses

C. By wearing a face shield

D. Any of the above

20 What units are used to measure noise?

A. Trebels

B. Decibels

C. Milibars

D. None of the above

Knowledge Area: Lubrication

21 A lubricant's viscosity is rated by what type of unit?

A. SUS
B. SAE
C. ISA
D. LVU

22 A lubricant with high viscosity has a:

A. High speed.
B. High temperature.
C. High resistance to flow.
D. High resistance to breakdown.

23 A low-viscosity lubricant:

A. Provides good cushioning for machine shock loads.
B. Can flow into tight spaces for better lubrication.
C. Does not carry heat away as well as high-viscosity lubricant.
D. Costs less than a high-viscosity lubricant.

24 What are two disadvantages of high-viscosity lubricants?

A. They are expensive and cannot be used on high-speed motors.

B. They break down quickly and are difficult to apply.

C. They do not flow well and do not carry heat away well.

D. They do not protect against abrasive action of dirt, and they break down quickly.

25 Multiple-viscosity lubricants differ from single-viscosity lubricants because:

A. They have special additive that extend their effective temperature range.

B. They are best within a very narrow temperature range.

C. They will never degrade under high temperatures.

D. They last longer.

26 One advantage of multiple-viscosity lubricants is that:

A. They flow better at medium range temperature than at either extreme.

B. They have a high bearing capacity.

C. They have a board working temperature range.

D. They do not break down in the presence of water.

27 Which of the following is NOT a factor affecting the selection of a lubricant?

A. Machine speed

B. Environmental humidity

C. Operating temperature

D. Environmental temperatures

28 When choosing a lubricant, you want:

A. The lubricant to stay thin at high temperatures.

B. The lubricant to thicken at low temperatures.

C. The lubricant to thin at low temperatures.

D. The lubricant to maintain effective viscosity at its highest rated temperatures.

29 An oil cooler is used to:

A. Add heat to the oil enable it to flow better at low temperatures.

B. Add heat to the oil to keep it from thinning at high temperatures.

C. Remove heat from the oil to prevent it from thinning at high temperatures.

D. Remove heat from the oil to prevent it from thickening at low temperatures.

30 What function do detergent additives in lubricants perform?

A. Keep metal surfaces clean

B. Keep the lubricant clean

C. Minimize the amount of foaming.

D. All of above.

31 An anti-forming additive in a lubricant:

A. Controls the level of dirt.

B. Controls the amount of mixing with air.

C. Controls the level of foaming.

D. Prevents the lubricant from mixing with metal particles.

32 As a mechanic, you observe that a machine bearing is extremely hot and becoming discolored as it operates. Your conclusion is that the:

A. Lubricant is contaminated by water.

B. Bearing is about to seize.

C. Lubricant is causing acid corrosion on the bearing.

D. Bearing is not compatible with the lubricant.

33 When cooling an overheated bearing, what should you do first?

A. Wrap the bearing housing in hot, wet rags.

B. Spray cool water on the bearing.

C. Inject cool oil in the bearing.

D. Wrap the bearing housing in cool, wet rags.

34 A grease cup is defined as a:

A. Cup filled with grease that screws onto a fitting.

B. Timed lubrication system controlled by a rotating cam.

C. Gravity system that forces lubricant onto or into the area needing lubrication.

D. Fitting that applies oil in droplet form.

35 A lubricating system used in low-speed applications in which a needle valve maters a steady rate of lubricant to a machine without recycling the lubricant is a(n):

A. Dip lubricator.

B. Shot lubricator.

C. Drip lubricator.

D. Oil sump.

36 A lubrication system in which the component needing lubrication rotates through an enclosed housing containing oil and carries the oil to other components is called a(n):

A. Dip lubricator.

B. Shot lubricator.

C. Drip lubricator.

D. Oil sump.

37 In a force-feed lubrication system, lubrication is moved to the component needing lubrication by a:

A. Cooler.

B. Pump.

C. Filter.

D. Bearing.

38 What is the most undesirable by-product of oil misting?

A. Bearing failure

B. Shaft damage

C. Explosion potential

D. Oil breakdown

Knowledge Area: Bearings

39 The two basic categories of bearings are:

A. Plain and antifriction.

B. Ball and roller.

C. Journal and ball.

D. Pillow-block and roller.

40 Bearings:

A. Are found in machines with moving parts.

B. Functions as guides.

C. Help reduce the friction between moving parts.

D. All of the above.

41Thrust bearings:

A. Support axial loads on rotating members.

B. Support radial loads on rotating members.

C. Both A and B.

D. None of the above.

42 Antifriction bearings:

A. Contain balls.

B. Contain rollers.

C. Will run hot if they are overlubricated.

D. All of the above.

43 Bearing lubrication systems include:

A. lubrication by hand.

B. Central grease systems.

C. Pressure-feed oil systems.

D. All of the above.

44 Plain bearings operate by:

A. Separating the races with balls or rollers.

B. Using an air gap.

C. Hydraulics.

D. Running on a film of lubricant.

45 Antifriction bearings operate by:

A. Separating the races with balls rollers.

B. Using an air gap.

C. Hydraulics.

D. Running on a film of lubricant

46 Roller bearings are used over ball bearings for which of the following situations?

A. High-speed applications

B. High-load applications

C. Wet environments

D. Mobile equipment engines

47 Bearing clearance can be described as:

A. The space between the rolling elements ant the races.

B. The allowed difference between the shaft size and the bearing inner race

C. The allowed differences between bearing inner and outer race.

D. None of the above.

48 Shaft tolerance can be defined as:

A. The allowed difference between the shaft size and the bearing inner

race.

B. The force applied during installation.

C. The space between the rolling elements and the races.

D. None of the above.

49 The preferred method for installing an antifriction bearing is:

A. With a sledge hammer.

B. To sand down the shaft until the bearing slides on.

C. With a bearing heater.

D. Both B and C.

50 When tightening the lock-nut on a spherical roller bearing, the preferred tool is:

A. A spanner wrench.

B. A bearing heater.

C. A hemmer and punch.

D. None of the above.

51 The bearing best suited for both radial and thrust loads is a ( ) bearing.

A. tapered-sleeve

B. liner-motion

C. needle

D. tapered-roller

52 A bearing lubricated with oil is capable of ( ) speeds than the same bearing lubricated with grease:

A. lower

B. higher

C. the same

D. different

53 As you tighten the nut on a spherical-roller bearing, the space between the race and the rolling elements:

A. Increase.

B. Decrease.

C. Remain the same.

D. Develops cracks.

54 A failed bearing that has a cracked inner race probably failed because:

A. the shaft was too large.

B. of a lack of lubricant.

C. the operator failed to do the proper inspection.

D. of overlubrication.

55 An antifriction bearing can run hot because:

A. of overlubrication.

B. it is about to fail.

C. of excessive load.

D. all of the above.

56 A 20% increase in bearing load, can result in a ( ) % decrease in bearing life.

A. 20

B. 100

C. 50

D. 10

Knowledge Area: Chain Drives

57 What is the maximum elongation that roller chain can tolerate before it should be replaced?

A. 10%

B. 3 inches

C. 3%

D. 3/16 inch per ft. of chain

58 What cause roller fatigue?

A. Lack of lubrication

B. Contamination

C. Improper chain tension

D. All of the above

59 What problems will chain misalignment cause?

A. Side plate water

B. Sprocket water

C. Pin water

D. Chain break

60 What are the two links that make up a standard roller chain?

A. Roller, rigid

B. Roller, pin

C. Master, half

D. Offset, half

61 What causes roller fatigue?

A. Lack of lubrication

B. Contamination

C. Improper chain tension

D. All of the above

62 What problems will chain misalignment cause?

A. Side plate water

B. Pin water

C. Chain break

D. All of the above

63 What is the tension or slack a roller chain is recommended to have?

A. 10% slack between centers

B. 1/2 inch slack

C. 5% slack between centers

D. 2% slack between centers

Knowledge Area: Belt Drives

64 Of the following, what are the four main types of belt drives?

A. V-belt; flat belt; timing belt; ribbed belt

B. Straight belt; V-belt; gear belt; ribbed belt

C. Rubber; vitron; buna-n, teflon

D. Round belt; dual face belt; V-belt; multibelt

65 Identify routine maintenance performed on flat belts.

A. Tensioning

B. Cleaning

C. Dressing

D. Both A and B

66 Which of the following is an acceptable V-belt installation process?

A. Reduce center-to-center distance of the pulleys.

B. Use a pry bar to slide the belt over the pulleys.

C. Tension the belt until your hand bounces off the belt.

D. All of the above.

67 Which of the following contribute to rapid belt wear?

A. Oil, dirt, heat, and misalignment

B. Water, dirt, sunlight, reflection, and direction

C. Guarding, shielding, reflection, and direction

D. Sunlight, dry-rot, mold, and water

68 Why do timing or gear belts not require high tension?

A. They do not require tensioning.

B. The material they are made of reduce slippage.

C. They provide slip-proof engagement.

D. There is not load fluctuation.

69 Belt drives are designed to transmit power between a drive unit and a:

A. Conveyor belt.

B. Motor.

C. Driven unit.

D. Roller.

70 When replacing one of a set of belts, the mechanic should:

A. Replace the worn belt only.

B. Replace the worn belt and the belt closer to the drive motor.

C. Replace all of the belts.

D. Replace the worn belt and the belt farthest from the drive motor.

71 The length of belt is determined by its:

A. Pitch line.

B. V-line.

C. Standard line.

D. None of the above.

72 When “timing” is a critical consideration with a belt, which of the following is typically used?

A. Joined belt

B. V-belt

C. Cogged belt

D. Positive drive belt

73 Regarding sheave grove angle, which of the following statements is correct?

A. Smaller diameter sheaves have less groove angel than larger diameter grooves.

B. Larger diameter sheaves have less groove angle than smaller diameter sheaves.

C. Groove angels are not affected by sheave diameter.

D. Can be compensated for by adjusting belt tension.

74 Which of the following conditions can cause excessive belt wear?

A. Dirty operating conditions

B. Improper sheave alignment

C. Improper tensioning

D. All of the above

Knowledge Area: Hydraulics

75 What function does a reservoir serve in a hydraulic system?

A. Store surplus of oil

B. Cools the oil

C. Cleans the oil

D. A, B, and C

76 Why is there a baffle in a hydraulic reservoir?

A. To prevent baffling

B. To assist in cleaning and cooling of the oil

C. To keep the oil level the same

D. To prevent overpressurization of the reservoir

77 What should the fluid pass through before it reaches the pump?

A. Prepump precipitator

B. Metal diffuser

C. Heat exchanger

D. Strainer

78 What are the three basic types of positive displacement pumps?

A. Centrifugal, gear, piston

B. Air pump, piston, centrifugal

C. Piston, gear, vane

79 What function does a relief valve provide in a hydraulic system?

A. Protects the system from overpressurization

B. Dumps oil back to the tank

C. Cools the oil

D. A and B

80 What function does a actuator serve in a hydraulic system?

A. To hold pressure in a system

B. To assist the pump in flow

C. To allow work to be performed

D. A and B

81 What are the four basic types of center conditions (envelops) in the directional control valves of a hydraulic system?

A. Open, close, tandem, return

B. Bidirectional, unidirectional, terminal, return

C. Tandem, float, closed, open

D. The center position is the same in all valves

82 What function do flow control valves serve in the hydraulic system?

A. Control pressure to a point in the system.

B. Control the speed of an actuator.

C. Reduce the speed of a pump.

D. Eliminate return in one direction.

83 What are the two basic types of flow control arrangements in a hydraulic system?

A. Meter in, meter out

B. Flow control, flow decontrol

C. Meter in, direct flow

D. Control, directional control

84 What are the two basic types of actuators in a hydraulic system?

A. Bladder, piston

B. Cylinder, motor

C. Double cylinder, single cylinder

D. Pump, actuator

85 Which of the following are means by which a directional control valve may be actuated?

A. Manual

B. Solenoid operated

C. Pilot pressure

D. All of the above

86 The variable volume pump used most often in high-pressure system is what type of pump?

A. Vane

B. Piston

C. Gear

D. Centrifugal

87 Basic hydraulics theory tells us that pressure:

A. On a confined liquid is transmitted undiminished in every direction.

B. Acts with equal force on equal areas.

C. Acts at right angels only on the container side walls.

D. Acts with equal force on reduced areas.

88 Hydraulics is the science of transmitting force or motion through a medium of a:

A. Confined liquid.

B. Nonconfined liquid.

C. A and B.

D. None of the above.

89 Component parts connected to each other by fluid lines in the hydraulic system form a:

A. Closed center system.

B. Bypass.

C. Circuit.

D. Motor.

90 A needle valve in a hydraulic line provide a:

A. Flow control orifice.

B. Pressure control orifice.

C. Relief valve.

D. Master valve.

Knowledge Area: Couplings

91 A major advantage of flexible couplings is that they:

A. Compensate for thermal expansion.

B. Provide greater torsional transfer than rigid couplings.

C. Require only minimal motor alignment.

D. Operate at higher rpm than rigid couplings.

92Name the two main groups of mechanical couplings:

A. Rigid and flexible.

B. Chain and gear.

C. Grid and Lovejoy.

D. Spring and centrifugal.

93 Which of the following couplings requires lubrication?

A. Slider

B. Steelflex

C. Torus rubber

D. Sure-Flex rubber

94 Measurements taken at the top and bottom of a coupling are taken to adjust:

A. Vertical alignment.

B. Horizontal alignment.

C. Angular alignment.

D. Parallel alignment.

95 When performing coupling alignment, the first activity that must be conducted is to:

A. Check runout.

B. Verify angular misalignment.

C. Verify parallel misalignment.

D. Check coupling spacing.

96 When a high-speed gear mesh coupling is removed from a compressor, the coupling is typically match marked. What is the purpose of this?

A. Ensures that it can be reassembled correctly.

B. Ensures that it is disassembled correctly.

C. Ensures that one coupling half is aligned to mesh.

97 Some centrifugal compressors use a high-speed gear-type coupling. How is this type of gear attached to the compressor shaft?

A. Bolted

B. Welded

C. Keyed

D. Interference fit

98 With high-speed gear couplings, gear teeth showing a large polished area indicate which of the following?

A. Proper gear mesh

B. Unit operation beyond recommended capacity

C. Gear wear

D. Galling

99 High-speed gear-type coupling for motor-to centrifugal compressor connections are typically lubricated by:

A. Grease.

B. Forces air.

C. Process fluid.

D. Oil.

100 Hose connections that are frequently made and “broken” would use which of the following types of couplings?

A. Flange

B. Push-on

C. Quick-connect

D. Reusable

Benchmark your mechanical knowledge:

Final Score: total of the scores/100 = ( )
60% or below = Needs extensive mechanical training
61% - 80% = Needs to review mechanical subject areas
81% - 90% = Needs mechanical training of intermediate level
91% - 100% = Needs advanced training

Answers :

1.C 2.A 3.C 4.A 5.C 6.A 7.B 8.C 9.A 10.D
11.B 12.C 13.D 14.A 15.B 16.B 17.A 18.D 19.A 20.B
21.A 22.C 23.B 24.C 25.A 26.C 27.B 28.D 29.C 30.A
31.C 32.B 33.C 34.A 35.C 36.A 37.B 38.C 39.A 40.A
41.A 42.D 43.D 44.D 45.A 46.B 47.A 48.A 49.C 50.A
51.D 52.B 53.B 54.A 55.D 56.C 57.C 58.A 59.B 60.B
61.D 62.D 63.D 64.D 65.A 66.A 67.A 68.C 69.C 70.C
71.A 72.D 73.A 74.D 75.D 76.B 77.D 78.C 79.A 80.C
81.C 82.B 83.A 84.B 85.D 86.B 87.A 88.A 89.C 90.A
91.A 92.A 93.A 94.A 95.D 96.C 97.C 98.D 99.C 100.C

Management Skills Assessment

Definition of a Skills Assessment

A maintenance skills assessment consists of a series of written tests, performance exercises, and identification activities selected from a listing of electrical basic skill areas.

Knowledge Assessment

This knowledge assessment is directed to the following skills :

- Shop safety and shop practices
- Lockout, tag-out
- Tools for electrical technicians
- Symbols and diagrams
- Overview of motor controls
- Power distribution and transformers
- Manual control devices
- magnets, solenoids, and relays

- Contactors and motor starters
- Pilot devices
- Photoelectric and proximity controls
- Timers, counters, and sequencers
- DC motors
- AC motors
- Motor control circuits
- Advanced motor control circuits : Accelerating and decelerating circuits
- AC and DC drives
- Programmable controllers
- Electronics for maintenance personnel
- Troubleshooting

Knowledge Area : Shop Safety and Shop Practices

1. The Class A type fire extinguisher is painted _____ and it is used for paper or wood fires.

   a. red

   b. green

   c. yellow

2. A GFI (ground fault interruption) receptacle is _____ .

   a. A special receptacle that has a third terminal for a ground wire.

   b. A special receptacle for power tools that allows more than one power tool to be plugged into it at the same time.

   c. A special circuit breaker that can determine if a short circuit occurs and automatically opens the circuit breaker to protect the circuit.

3. A two-handed pushbutton station is _____ .

a. a safety circuit that requires an operator of a stamping press to have both hands on a button for the press to begin its cycle.

b. a convenience circuit that allows an operator to operate the press from two different locations.

c. a single pushbutton that has an oversize spring that requires the operator to use both hands to depress it.

4. Ear protection should be used _____ .

a. at all times even in locations with moderate or small amounts of noise because this noise is damaging over a long period of time.

b. only in high noise areas.

c. only if a person has been tested and found to have some hearing loss.

5. If an electrical power tool has a power cord with a three-prong plug, and the only electrical outlet has two prongs, you should _____ .

a. cut the third prong (ground lug) off the power cord so that you can use the outlet.

b. find an adapter that allows you to plug a three-prong plug into a two-prong outlet.

c. not use this outlet because the power tool needs to be grounded for safe operation, and the two-prong outlet is not grounded.

Knowledge Area : Lockout, tag-out procedures

6. Who is responsible for creating the lockout, tag-out procedures in a factory?

a. OSHA (occupational safety and health administration)

b. Each worker should create his or her own procedure.

c. Each factory should create its own procedure.

7. The forms of energy that you should be aware of during a lockout procedure include _____

a. A hydraulic and electrical power.

b. Hydraulic, electrical and potential energy sources such as gravity.

c. Only electrical power sources.

8. If an employee on the day shift places a padlock on a lockout device, and a second-shift employee completes the repair, _____

a. the second-shift supervisor can remove the first-shift padlock.

b. the second-shift employee can remove the first-shift padlock.

c. No one on the second shift can remove the padlock; it cannot be removed until the employee that placed the padlock on the lockout comes back to work.

9. Prior to removing a padlock from a lockout device and restarting a machine, you should _____

a. Replace all guards and turn on the power.

b. alert all employees in the area that work on this machine that you are turning on the power and starting the machine.

c. call the operator to start the machine.

10. The major problem with potential energy sources during a lockout procedure is that _____

a. the hazard they present may not be readily apparent, such as a machine part that is supported by hydraulic pressure that will drop when the pressure is released.

b. potential energy is much more dangerous than electricity.

c. potential energy is not a real threat, like kinetic energy, so it can be ignored.

Knowledge Area : Tools for electrical technicians

11. Which tool would you use to strip a wire to remove its insulation?

    a. Wire cutters

    b. Common pliers

    c. Wire strippers

    d. Side-cut pliers

12. A scopemeter can _____

    a. display voltage as a number.

    b. display the waveform of the voltage being measured.

    c. display the frequency of the voltage being measured.

    d. All of the above

13. Offset screwdrivers are used to _____

    a. provide more torque than a regular screwdriver.

    b. tighten or loosen hard to reach screws that have small clearance or are in tight spaces.

    c. reach screws in deep recesses.

    d. All of the above

14. A nut driver is _____

    a. a type of pliers.

    b. a type of wrench.

    c. a tool used to strip wires.

    d. a special offset screwdriver.

15. A tap and die set are used in this way :

    a. The tap makes interior threads and the die makes exterior threads.

    b. The tap makes exterior threads and the die makes interior threads.

    c. The tap can make both interior and exterior threads.

    d. The die can make both interior and exterior threads.

    e. Both c and d.

Knowledge Area : Symbols and diagrams

16. The wiring diagram _____

a. shows the location of each part in the electrical cabinet.

b. indicates the sequence of operation for the machine.

c. is also called an elementary diagram.

d. All of the above.

17. The numbers along the side of a ladder diagram _____

a. indicate the rung number for the diagram.

b. can be used for cross-reference purposes.

c. indicate the number of parts in that line of the diagram.

d. All of the above

e. Only a and b

18. The symbol for a switch that is operated by pressure _____

a. can be used as the symbol for a pressure switch.

b. can be used as the symbol for a vacuum switch.

c. can be used to indicate a temperature-operated switch.

d. All of the above

e. Only a and b

19. The parts list in a set of blueprints _____

a. indicates the part number of each component in the system.

b. indicates the number of each part used in the system.

c. indicates the size or rating for the part.

d. All of the above

e. Only a and c

20. The dashed line that connects two switch contacts that are in different lines of a ladder diagram indicates that _____

a. the sets of contacts are actually mounted in the same switch and are activated by the same switch operator.

b. the two sets of contacts are mounted in the same switch, but are activated by separate switch operators.

c. the sets of contacts are controlled by the same type of switch, but are not connected in any other way.

d. All of the above

Knowledge Area :Overview of motor controls

21. Two-handed palm start buttons that require an operator to have one hand on each button to start the machine are an example of _____

a. operational controls.

b. safety controls.

c. process controls.

d. motion controls.

22. A limit switch that indicates midtravel location on a machine is an example of _____

a. operational controls.

b. safety controls.

c. process controls.

d. All of the above

23. The coil of a motor starter is usually found in the _____

a. control circuit.

b. load circuit.

c. safety circuit.

d. All of the above

24. A pump motor that is connected to the contacts of a motor starter is usually found in the _____

a. control circuit.

b. load circuit.

c. safety circuit.

d. All of the above

25. Solid-state controls may include _____

a. transistors.

b. SCRs.

c. op-amps.

d. All of the above

Knowledge Area : Power distribution and transformers

26. A delta-wired transformer will have _____ at its secondary terminals.

a. 100 V

b. 208 V

c. 230 V

d. 330 V

27. A wye-wired transformer will have _____ at its secondary terminals.

a. 100 V

b. 208 V

c. 23 0 V

d. 330 V

28. A single-element fuse _____

a. has a single element that protects against slow overcurrents.

b. has a single element that protects against short-circuit current.

c. has two elements that protect against both short-circuit current and slow overcurrents.

d. is rated for a single voltage.

29. A dual-element fuse _____

a. has a single element that protects against slow overcurrents.

b. has a single element that protects against short-circuit current.

c. has two elements that protect against both short-circuit current and slow overcurrents.

d. is rated for two voltages.

30. The rejection feature in a fuse _____

a. ensures that the fuse cannot be used in a circuit that has a larger current rating than the fuse.

b. ensures that the fuse cannot be used in a circuit that has a smaller current rating than the fuse.

c. ensures that a dual-element fuse cannot be replaced with a single-element fuse.

d. All of the above

Knowledge Area : Manual control devices

31. The function of the overload and heater on a manual starter is to _____

a. ensure that the temperature of the motor starter remains constant.
b. ensure that motors that are connected to the manual motor starter cannot receive excessive current.
c. allow the motor to be reversed quickly.
d. ensure that the temperature of the motor remains constant.
e. Both a and d

32. The type 1NEMA enclosure is rated for _____

a. drip-proof indoor use.
b. general purpose indoor use.
c. dust-tight indoor use.
d. rainproof outdoor use.

33. When you test a drum switch for continuity, which of the following would you expect to see when the switch is in the forward position?

a. Continuity between terminals 1 and 3

b. Continuity between terminals 2 and 4

c. Continuity between terminals 5 and 6

d. All of the above

e. Only a and b

34. If an overload cannot be reset immediately after it has tripped, the problem may be that _____

a. the solder in the overload is not solidified yet.

b. the motor has an open winding.

c. the motor starter needs its fuses replaced.

d. the start button is defective.

35. A size 1 motor starter is rated for _____ three-phase (poly phase) motor at 230 V.

a. 1 hp

b. 3 hp

c. 7.5 hp

d. 10 hp

Knowledge Area : Magnets solenoids, and relays

36. _____ can have the strength of its field changed easily.

    a. A permanent magnet

    b. An electromagnet

    c. A dipole

37. The polarity of an electromagnet can be changed by _____

    a. changing the direction of current flow through the coil of wire.

    b. changing the amount of current flow through the coil of wire.

    c. changing the frequency of the current flow through a coil of wire.

38. A laminated steel core is used in electromagnets that have AC voltage applied to them because _____

a. laminated steel is more economical to use than soft iron.

b. laminated steel is easily formed to any shape, which makes it more usable in complex components.

c. laminated steel allows the magnetic field to build and collapse quickly.

39. A magnetic field is created in a coil of wire when _____

a. current flows through the wire.

b. current stops flowing through a wire.

c. the coil has a core.

40. The left-hand rule is used to _____

a. determine the amount of magnetic flux in a coil.

b. determine the number of coils in an electromagnet.

c. determine the polarity of the magnetic field in an electromagnet.

Knowledge Area : Contactors and motor starters

41. You will find the identifications _____ on a motor starter.

    a. L1 on the line side and T1 on the load side

    b. T1 on the line side and L1 on the load side

    c. L1 on the line side and the load side of the first set of contacts

    d. T1 on the line side and the load side of the first set of contacts

42. IEC stands for _____

    a. Inductive/electrical-rated contactor.

    b. International electrical contactor.

    c. International electro-technical commission.

    d. Inductive-type contactor.

43. The main difference between NEMA and IEC standards is that _____

a. IEC devices are larger than NEMA devices with the same current rating.

b. IEC devices are smaller than NEMA devices with the same current rating.

c. there is no difference in size between NEMA and IEC components.

d. IEC devices can be used only in foreign equipment.

44. An overload in a motor starter _____

a. provides protection against overcurrent.

b. provides protection against overvoltage.

c. provides protection against both overvoltage and overcurrent.

d. provides protection against motor overspeed.

e. All of the above

45. A eutectic-type overload is different than a bimetal type overload because _____

a. the eutectic type operates on the principle of low temperature solder and the bimetal type operates on the principle of dissimilar metals.

b. the bimetal type operates on the principle of low temperature solder and the eutectic type operates on the principle of dissimilar metals.

c. the eutectic type works better for three-phase motors.

d. the bimetal type works better for three-phase motors.

Knowledge Area : Pilot devices

46. A limit switch can be tested by _____

    a. an ohmmeter if the switch is out of circuit.

    b. a voltmeter if the switch is in circuit and has power applied.

    c. manually activating the switch

    d. All of the above

47. The differential pressure switch is _____

    a. activated by a diaphragm mechanism similar to a low pressure switch and checks the difference between two pressures.

    b. activated by a rubber bellows.

    c. activated by a spring and balance mechanism.

    d. activated by a metal bellows.

48. The joystick control _____

a. consists of a multiple set of switch contacts located so that the stick's movement will activate one or more contacts at the same time.

b. is mainly a video game controller.

c. is a type of limit switch.

d. is a type of pushbutton.

49. The foot switch is _____

a. a type of limit switch.

b. similar to a pushbutton switch, except that it is activated by pressing on it with your foot.

c. similar to a pressure switch, since the pressure of your foot activates the switch.

d. similar to a joystick control, since it is operated with a variety of motions.

50. A float switch is _____

a. a specialized pilot device used to measure the level of liquids or granular materials used in industry.

b. a specialized switch that measures the presence of liquid flow.

c. a specialized switch that measures the presence of granular flow.

d. Both b and c

Knowledge Area : Photoelectric and proximity controls

51. The term ECKO means _____

a. electrical circuit kinetic oscillator.

b. eddy current killed oscillator.

c. electrical current kinetic oscillator.

d. a proximity switch that bounces signals off its target and receives the echo.

52. The difference between an inductive proximity switch and a capacitive proximity switch is _____

a. the inductive proximity switch is activated by nonmetal parts and the capacitive proximity switch is activated by metal parts.

b. the inductive proximity switch is activated by metal parts and the capacitive proximity switch is activated by nonmetal parts.

c. the inductive switch is more accurate.

d. the capacitive switch is more accurate.

53. A modulated light source for a photoelectric device consists of _____

a. a light-emitting diode (LED).

b. a phototransistor.

c. an oscillator circuit.

d. All of the above

54. The retroreflective photoelectric switch _____

a. has the modulated light source and the receiver in the same housing.

b. has the modulated light source and the receiver in separate housings.

c. uses a reflector to send light back to the receiver.

d. All of the above

e. Both a and c

55. A diffuse scan photoelectric switch _____

a. operates on the principle of emitting a beam of light on an object rather than on a reflector.

b. operates on the principle of emitting a beam of light on a reflector rather than on an object.

c. must use fiber optic cables.

d. All the above

Knowledge Area :Timers, counters and sequencers

56. The main difference between a reset timer and a repeat cycle timer is that _____

a. the reset timer is activated and then it times out and actuates a set of contacts and the repeat cycle timer continually repeats its cycle and actuates a set of contacts at the end of each cycle.

b. the repeat cycle timer is activated and then it times out and actuates a set of contacts and the reset timer continually repeats its cycle and actuates a set of contacts at the end of each cycle.

c. the repeat cycle timer uses a pneumatic controller while the reset timer uses a mechanical-type timer.

d. There is no real difference between the two types of timers.

57. Timers provide time delay by using _____

a. motors, gears, and cams to control sets of contacts.

b. air or liquid in a chamber that empties slowly to cause a delay in the action of contacts.

c. solid-state components.

d. All of the above

58. When discussing the electrical symbol for the time, which of the following is true?

a. The time-delay-on symbol uses the lower half or tail of the arrow.

b. The time-delay-off symbol uses the upper half or arrowhead portion of the arrow.

c. The time-delay-on timer can have both normally open and normally closed contacts.

d. The time-delay-off timer can have both normally open and normally closed contacts.

e. All of the above

f. Only a and b

59. When discussing the pneumatic timer, which of the following is true?

a. air is released from the chamber through an orifice controlled by a needle valve to control the amount of time delay.

b. The needle valve controls the rate at which air can leave the chamber.

c. when the pneumatic switch is reset, the chamber is refilled with air.

d. When a sufficient amount of air has been released, the spring will cause the diaphragm to move far enough to activate the electrical switch element.

e. All of the above

f. Only a and b

60. What type of counter could you encounter when you are on the job?

a. A mechanical counter that consists of a set of gears and wheels with the numbers 0 through 9 listed on them.

b. A reset or cycle counter that operates on electro-mechanical principles where the signal that causes the counter to advance one count comes from an electrical signal instead of through mechanical movement of an arm.

c. A solid-state counter that utilized CMOS solid-state circuitry to execute the counter function.

d. All of the above

e. Only a and b

Knowledge Area : DC motors

61. The armature in a DC motor is _____

a. the rotating part of the motor.

b. the part of the motor that makes contact with the brushes.

c. made of heavy wire and is mounted in the stationary part of the motor.

d. made of light-gauge wire and is mounted in the stationary part of the motor.

e. All of the above

62. The series field in a DC motor is _____

a. the rotating part of the motor.

b. the part of the motor that makes contact with the brushes.

c. made of heavy wire and is mounted in the stationary part of the motor.

d. made of light-gauge wire and is mounted in the stationary part of the motor.

e. All of the above

f. Only a and b

63. The commutator in a DC motor is _____

a. the rotating part of the motor.

b. the part of the motor that makes contact with the brushes.

c. made of heavy wire and is mounted in the stationary part of the motor.

d. made of light-gauge wire and is mounted in the stationary part of the motor.

e. All of the above

f. Only a and b

64. The function of the end plates on a DC motor is to _____

a. provide a mounting for the armature bearings.

b. provide support for the armature shaft.

c. provide a mounting point for the brush rigging.

d. All of the above

e. Only a and b

65. You can reverse the direction of a DC motor by _____

a. reversing the field winding if the motor is a series motor.

b. reversing the field winding if the motor is a shunt motor.

c. reversing the armature winding if the motor is a series motor.

d. All of the above

e. Only a and b

Knowledge Area : AC motors

66. The start winding is connected in _____with the run winding for a split-phase AC single-phase motor.

a. series

b. parallel

c. series parallel

67. The speed of an AC motor can be increased by _____

a. decreasing the frequency of the supply voltage to the motor.

b. increasing the frequency of the supply voltage to the motor.

c. increasing the amount of voltage to the motor.

68. The single-phase induction motor needs a start winding _____

a. to create a phase shift that will provide starting torque.

b. to increase the speed of the motor.

c. to create additional running torque.

69. The shaded-pole, single-phase motor _____

a. uses a relay to remove its start winding from the circuit after the motor starts.

b. uses a capacitor to remove the start winding from the circuit after the motor starts.

c. does not have start winding, since it has a shading pole to provide the phase shift for starting.

70. The rated speed of a four-pole AC motor is _____

a. 3600 rpm.

b. 1800 rpm.

c. 1200 rpm.

Knowledge Area : Motor control circuits

71. If you add multiple stop pushbuttons to a three-wire control circuit, the extra stop buttons should be _____

a. wired in parallel with the start pushbutton.

b. wired in series with the start pushbutton.

c. wired in parallel with the stop pushbutton.

d. wired in series with the stop pushbutton.

72. If you add multiple start pushbuttons to a three-wire control circuit, the extra start buttons should be _____

a. wired in parallel with the start pushbutton.

b. wired in series with the start pushbutton.

c. wired in parallel with the stop pushbutton

d. wired in series with the stop pushbutton

73. In a jog circuit the jog switch should be _____

a. wired in series with the start pushbutton.

b. wired in parallel with the coil of the motor starter.

c. wired in series with the auxiliary contacts that are used to seal in the start pushbutton.

d. wired in parallel with the auxiliary contacts that are used to seal in the start pushbutton.

e. All of the above

74. The _____ is connected in series with the start winding for a permanent split-capacitor (PSC) motor.

a. start capacitor

b. run capacitor

c. potential relay

75. If you add an indicator lamp to a circuit, the lamp should be wired _____

a. in series with the motor starter coil.

b. in parallel with the motor starter coil.

c. in series with the auxiliary contacts.

d. in parallel with the auxiliary contacts.

Knowledge Area : Advanced motor control circuits : accelerating and decelerating circuits

76. Acceleration circuits allow motors to come up to speed without drawing excessive locked-rotor current (LRA). Locked-rotor current can be controlled by _____

a. reducing the amount of voltage supplied to the motor through primary resistors.

b. reducing the amount of voltage supplied to the motor through the transformer.

c. changing the winding configuration of the motor during the starting.

d. All of the above

e. Only a and b

77. The wye-delta starter controls starting current by allowing a three-phase motor to be started _____

a. as a wye-connected motor and switched to a delta-connected motor after the motor is up to speed.

b. as a delta-connected motor and switched to a wye-connected motor after the motor is up to speed.

c. as a delta-connected motor and switched to a star-connected motor after the motor is up to speed.

d. All of the above

78. Electromechanical brakes are used to slow or stop a motor by _____

a. having the electric coil energized when the motor is running and deenergized to allow the mechanical brakes to engage.

b. having the electric coil deenergized when the motor is running and energized to allow the mechanical brakes to engage.

c. having the electric coil energized when the motor is running and energized to allow the mechanical brakes to engage.

79. A plugging circuit _____ to cause the motor to decelerate.

a. connects a motor in reverse

b. applies a mechanical brake

c. applies an electromechanical brake

d. uses a solid-state circuit

80. A regenerative braking system _____ to cause the motor to decelerate.

a. applies a mechanical brake

b. disconnects voltage from the motor windings and reconnects the windings as a generator

c. applies an electromechanical brake

d. uses a solid-state circuit

Knowledge Area : AC and DC drives

81. Which of the following is not controlled by parameters on a variable frequency drive?

a. Ramp-up speed

b. Ramp-down speed

c. Boost voltage

d. Braking functions

e. None of the above

82. Variable frequency drives are widely used to control the speed of _____

a. conveyor systems.

b. blower speeds.

c. pump speeds.

d. machine tool speeds.

e. All of the above

83. The three main types of circuits used in a drive are called _____

a. CSI, VVI and PWM.

b. CCS, VVI and PWM.

c. CSI, VVI, and PWI.

d. CSI, VFD, and PWM.

84. Typical DC drives use _____ in their circuits for control.

a. light-emitting diodes (LEDs)

b. silicon-controlled rectifiers (SCRs)

c. field-effect transistors (FETs)

d. All of the above

85. The filter circuit of a VFD consists of _____

a. an inductor (choke) and capacitor.

b. a fuse and capacitor.

c. a fuse and inductor.

d. an MOV and fuse.

Knowledge Area : Programmable controllers

86. When the input contact that enables a TON-type timer is opened, the accumulated value in the timer will _____

a. reset (go to zero).

b. freeze (remain at its present value).

c. go to an undermined value and the timer must be set manually.

87. An RTO-type (retentive) timer has its accumulative value reset _____

a. any time the enable contacts are opened.

b. only when the reset for the timer is “HI”.

c. any time power is passed to the RES (Resetting) instruction.

88. When the PLC processor is in the PROGRAM mode, _____

a. it executes its scan cycle.

b. it does not execute its scan cycle.

c. it is impossible to tell whether the processor is executing its scan cycle because you are not on line.

89. When it is used as part of a start/stop circuit for a PLC system, the stop pushbutton should be wired _____ and programmed _____

a. normally closed, normally open.

b. normally open, normally closed.

c. It doesn't matter.

90. You can use the _____ on the face of a PLC to determine whether an input switch is on or off.

a. power light

b. input status indicators

c. output status indicators

Knowledge Area : Electronics for maintenance personnel

91. A PN junction is forward biased when _____

    a. positive voltage is applied to the P material and negative voltage is applied to the i material.

    b. negative voltage is applied to the N material and negative voltage is applied to the P material.

    c. its junction has high resistance.

92. The rectifier _____

    a. converts DC voltage to AC voltage.

    b. converts AC voltage to DC voltage.

    c. can be used as a seven-segment display for numbers.

93. A circuit that has one SCR in it can _____

    a. control AC voltage.

    b. control DC voltage.

    c. control both AC and DC voltage.

94. The transistor operates similar to a relay in that _____

    a. its emitter is like the coil and its base and collector are like a set of contacts.

    b. its collector is like the coil and its base and emitter are like a set of contacts.

    c. its base is like a coil and its emitter and collector are like a set of contacts.

95. The sold-state relay _____

    a. uses an LED to receive a signal and a transistor to switch current.

    b. uses a capacitor to receive a signal and an IC to switch current.

    c. uses a transistor to receive a signal and an IC to switch current.

Knowledge Area : Troubleshooting

96. A wiring diagram _____

    a. shows the sequence of operation for the circuit.

    b. shows the location of each component in the circuit.

    c. shows how each component operates.

    d. shows how a machine should troubleshooted.

97. A ladder diagram _____

    a. shows the sequence of operation for the circuit.

    b. shows the location of each component in the circuit.

    c. show how each component operates.

    d. shows how a machine should be troubleshooted.

98. Troubleshooting may best be described as _____

    a. finding the part of the machine that is broken.

    b. identifying the parts of a machine that are working correctly and through a process of elimination determining what is faulty.

    c. swapping parts until the machine starts running again.

    d. removing parts from a machine and testing each one with an ohmmeter.

99. The control circuit _____

    a. includes the motor and other loads in a circuit.

    b. includes the motor and other controls in a circuit.

    c. includes switches and other controls in a circuit.

    d. All of the above

100. The load circuit _____

a. includes the motor and other loads in a circuit.

b. includes the motor and other controls in a circuit.

c. includes switches and other controls in a circuit.

d. All of the above

Benchmark your electrical knowledge:

Final Score: total of the scores/100 = ( )

60% or below = Needs extensive electrical training

61% – 80% = Needs to review electrical subject areas

81% – 90% = Needs electrical training of intermediate level

91% – 100% = Needs advanced training

Answers :

1.b	2.a	3.a	4.a	5.c	6.c	7.b	8.a	9.b	10.a
11.c	12.d	13.b	14.b	15.a	16.a	17.e	18.a	19.d	20.a
21.b	22.a	23.a	24.b	25.d	26.c	27.b	28.b	29.c	30.b
31.b	32.b	33.d	34.a	35.c	36.b	37.a	38.c	39.a	40.c
41.a	42.c	43.b	44.a	45.a	46.d	47.a	48.a	49.b	50.a
51.b	52.b	53.d	54.a	55.a	56.a	57.d	58.e	59.e	60.d
61.a	62.c	63.b	64.d	65.d	66.b	67.b	68.a	69.c	70.b
71.d	72.a	73.c	74.b	75.d	76.d	77.a	78.a	79.a	80.b
81.e	82.e	83.a	84.b	85.a	86.a	87.c	88.b	89.a	90.b
91.a	92.b	93.b	94.c	95.a	96.b	97.a	98.b	99.c	100.a